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Tech Notes

November 1989

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Technology fact sheets from Federal laboratories

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Tech Notes

Highlighting Selected U.S. Government Technology & Resources

November 1989

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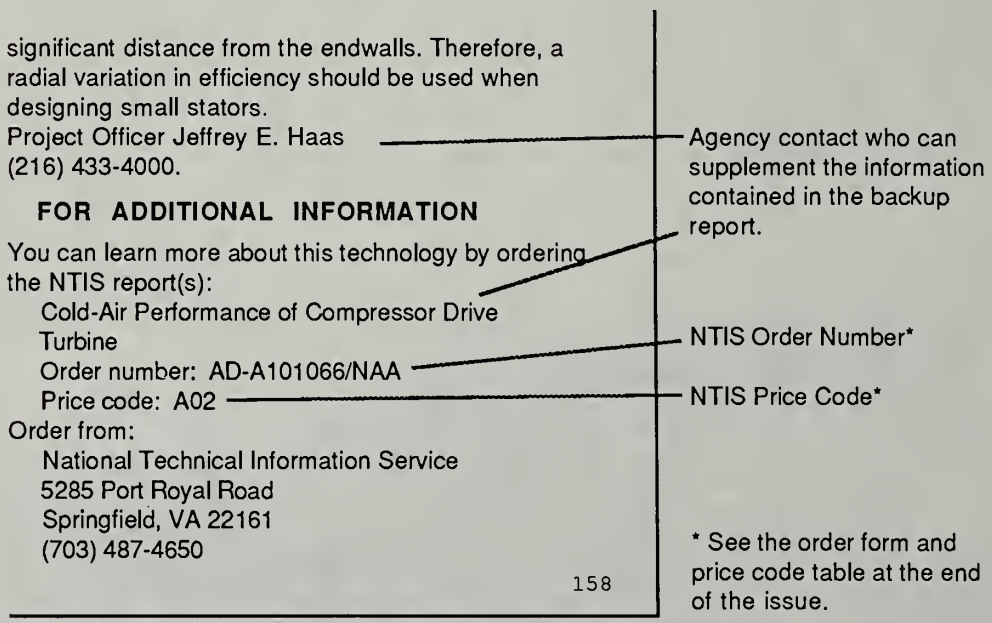
significant distance from the endwalls. Therefore, a radial variation in efficiency should be used when designing small stators.
Project Officer Jeffrey E. Haas
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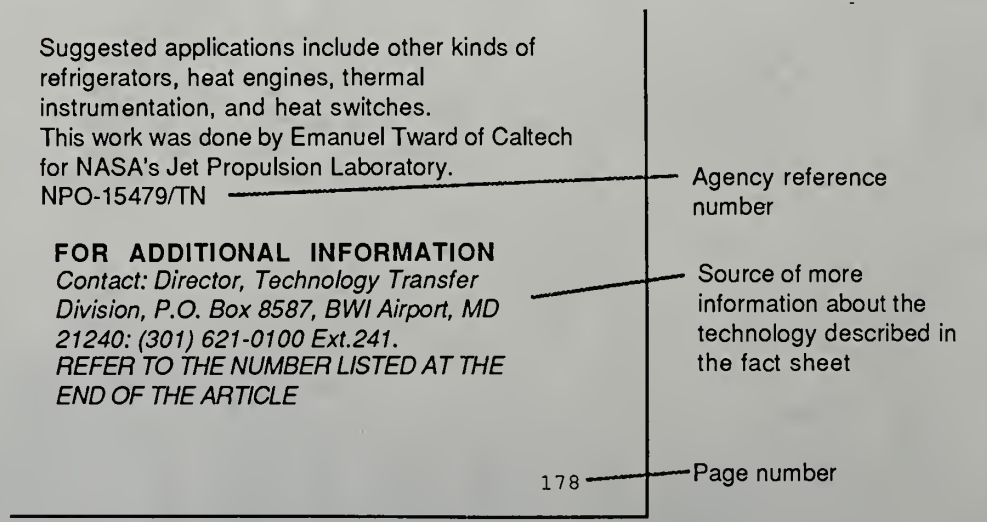
Suggested applications include other kinds of refrigerators, heat engines, thermal instrumentation, and heat switches.
This work was done by Emanuel Tward of Caltech for NASA's Jet Propulsion Laboratory.
NPO-15479/TN
FOR ADDITIONAL INFORMATION
Contact: Director, Technology Transfer Division, P.O. Box 8587, BWI Airport, MD 21240: (301) 621-0100 Ext.241.
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0971 AutoCAD-to-NASTRAN Translator Program—This program facilitates the creation of finite-element mathematical models from geometric entities.

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0954 Zinc-Containing Wastes Used for Electrogalvanizing

0961 AutoCAD-to-GIFTS Translator Program—Data from drafting programs are used to create finite-element mathematical models.

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0976 Joining Ceramics

0977 Deposition of Pinhole-Free CoSI2 Film—A stoichiometric combination of cobalt and silicon is overlaid with silicon. (Licensing Opportunity)

0978 Glass Coats for Hot Isostatic Pressing—Surface voids would be sealed from pressurizing gas.

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0980 Molecular-Beam Epitaxy of CrSI2 on Si(111)—Crystalline layers have been grown in a commercial apparatus.

0981 Resistance to Delamination in Composite Materials—A fracture-mechanics approach is applied to delamination failures. (Licensing Opportunity)

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Agriculture & Food

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Research Technology
Agricultural Research Service
U.S. Department of Agriculture

Licensing Opportunity

Robotic Seedling Transplanting System

A robot that doesn't mind monotonous, backbreaking work could one day help automate the labor-intensive raising, shipping and transplanting of vegetable and tree seedlings into fields, nurseries and greenhouses. Researchers have designed and filed for a patent on the first component of a robotic transplanting system that could work at least four times faster than human-dependent systems, with each row in the machine processing and planting 180 to 240 seedlings per minute vs. a typical 40 by hand. The device, which could be mounted on today's farm machinery, removes seedlings from shipping containers and plants them one at a time into rows of a field. When complete, the system could plant seeds, automatically cull unusable seedlings and empty containers in which seeds did not germinate and transfer the rest from growing trays to shipping containers from which they can be transplanted into the fields. If the automated system is completed and becomes widely used in the industry, it could eventually reduce costs to less than one-half that of hand labor, open up major new markets and help the U.S. horticultural industry to be competitive on a global basis.

FOR ADDITIONAL INFORMATION: A copy of this invention's patent is available from the U.S. Commissioner of Patents, Washington, DC 20231 for $1.50. Inquiries concerning rights for commercial use of this invention should be addressed to: Office of Federal Patent Licensing, Center for the Utilization of Federal Technology, Room 304, NTIS, Springfield, VA 22161; (703)487-4738.

To Discuss This Effort Further Contact: Harold L. Brewer; (912)386-3666, Crop System Research, Tifton, GA

Research Technology
Agricultural Research Service
U.S. Department of Agriculture

Sugar Beets Breathe Lightly, Save Energy

Each year, 9 million tons of U.S. sugar beets lie in piles for an average 60 days awaiting processing. As they lie around, the beets are using up part of their sugar as energy.

Just breathing to stay alive during this time causes them to consume as much energy as 9 million people would require in 3 weeks on a 2,500-calorie diet.

Add to that energy waste the amount used by storage-rot fungi, and processors face a loss of 500 million pounds of sugar annually, says Larry G. Campbell, an Agricultural Research Service geneticist based at Fargo, North Dakota.

Now for the first time, Campbell and his ARS and North Dakota State University colleagues have developed for plant breeders sugar beets that respire lightly while resisting three of the most prevalent storage rot fungi.

Respiration rates of the new sugar beet breeding lines averaged 27 percent less than rates of standard commercial hybrids, and storage rot proceeded at a 55-percent slower pace. When used to produced hybrids, these breeding lines will have the potential to increase the amount of sucrose that can be recovered after storage.

Usually, plant breeders must cross a number of breeding lines to develop new varieties with numerous desired traits such as those relating to sugar yield and resistance to pests.

Campbell says, "We expect that our new germplasm, designated F1009, with multiple storage traits will

More than a half-billion pounds of sugar may be lost while beets await processing.

expedite efforts to help farmers and processors with a more productive beet."

One of the storage rot fungi thwarted by F1009 is *Phoma betae*. This organism of decay occurs throughout the world and is prevalent along the Red River Valley in North Dakota and Minnesota. The other resisted fungi, *Botyrtis cinerea* and *Penicillium claviforme*, are probably the two most costly storage rot organisms of sugar beets on a worldwide scale.

To develop the germplasm, the scientists first randomly interpollinated 19 plants of diverse backgrounds previously selected for either low respiration or disease resistance. They harvested seed from each cross, separately identifying it as a family. After identifying family progeny with both desired traits, the researchers began the next cycle of pollination and selection.

After four cycles, Campbell found no strong relationship between storability traits and root yield or sucrose content. This would indicate that storage-trait genes can be bred into commercial varieties without loss of yield.

Larry G. Campbell is in USDA-ARS Sugarbeet Research, Northern Crop Science Laboratory, North Dakota State University, P.O. Box 5677, University Station, Fargo, ND 58105 (701) 239-1357. ◆

Research Technology *Licensing Opportunity*
Agricultural Research Service
U.S. Department of Agriculture

Soy-Based Products can be Tested for Protease Inhibitors

Infant formulas, diet shakes and other soy-based products can be easily and accurately checked by two new tests for traces of natural compounds known as protease inhibitors. If they aren't stopped by heat or chemical treatment, these compounds block helpful enzymes the body needs to digest incoming protein. Food processors can use the new monoclonal antibody tests to make sure their products are free of or contain only low levels of the inhibitors. One test reveals levels of the Kunitz-type inhibitor, the other screens for the Bowman-Birk type. Other prospective users of the new tests include researchers who want to develop soybean varieties low in both types of inhibitors and scientists who are investigating whether the inhibitors can fight cancer.

FOR ADDITIONAL INFORMATION: A copy of this invention's patent is available from the U.S. Commissioner of Patents, Washington, DC 20231 for $1.50. Inquiries concerning rights for commercial use of this invention should be addressed to: Office of Federal Patent Licensing, Center for the Utilization of Federal Technology, Room 304, NTIS, Springfield, VA 22161; (703)487-4738.

To Discuss This Effort Further Contact: D. L. Brandon, A. H. Bates, or M. Friedman; (415)559-5783, Food Safety Research, Western Regional Research Center, Albany, CA.

Research Technology
Agricultural Research Service
U.S. Department of Agriculture

Which Little Pig Is Fated To Be Fat?

ARS scientists have a new test that could help livestock breeders produce leaner pigs and other meat animals.

"Fat-conscious consumers are shifting toward less and leaner meat. From 1980 to 1987, per capita consumption of pork dropped about 13 percent. To stay competitive at the meat counter, the pork industry has to produce a pig with less fat," says ARS physiologist Gary J. Hausman.

Fat is a major contributor to health problems in the United States today. It has been implicated in adult-onset diabetes, heart attack, stroke and kidney problems, and a host of other maladies. ARS scientists are studying ways to reduce the amount of fat in pigs and other livestock.

"We are developing a test for obesity in very young animals," says Hausman, who is with the Animal Physiology Research unit in Athens, Georgia. "We can tell with a harmless blood test which young pigs will be fat and which will be lean."

The test would reveal to breeders and farmers which pigs in a litter will become lean adults. That could save time and money wasted in raising and breeding pigs that are fated to be fat.

Hausman describes the test. "We first have to grow rat adipose or fat cells in culture. Specifically, we need pre-adipocytes, that is, rat cells before they develop globules of oily fat in their cytoplasms."

To separate out the pre-fat cells, a sample of rat fat cells is placed in a digesting medium to dissolve the glue that binds the cells together. The cells are then centrifuged to bring down the pre-fat cells since the fat globules in the more mature fat cells make them float. The separated pre-fat cells are then cultured in a growth medium.

To run the test, about 10 milliliters of blood serum from the subject pig is placed in the growth medium of the pre-fat cell cultures. In 7 to 8 days, the cultures are tested for the enzyme glycerol phosphate dehydrogenase.

"We found that cultures given serum from pigs that were genetically destined to be fat when they matured had four times as much enzyme compared to serum from lean pigs of the same age," says Hausman.

"It's clear the test works." But he adds, "It won't be practical for production until we can skip the cell culture phase and test serum directly for the chemical that makes the rat pre-fat cells produce more glycerol phosphate dehydrogenase."

"In the future, a practical test for obesity may have a use in human medicine," Hausman says. "It would alert physicians and parents of the possibility of a child's becoming an obese adult. An early program of diet, exercise, and possibly medical treatment might prevent adult obesity."

Gary J. Hausman is with the USDA-ARS Animal Physiology Research Unit, Room 305, Richard B. Russell Agricultural Research Center, P.O. Box 5677, College Station Rd., Athens, GA 30613 (404) 546-3224. ✦

Computers

0934 Neural Networks Improve Data Analysis

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0936 Passivity in Analysis of Robustness of a Control System—A robustness margin (a measure of the degree of passivity) is defined.

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Technology Application

Pacific Northwest Laboratory

Neural Networks Improve Data Analysis

Researchers at the Pacific Northwest Laboratory (PNL) have successfully applied a new technology that may lead to improved and cost-effective means for solving problems such as reducing and analyzing the large amount of data generated in metering energy use. A PNL-developed artificial neural system simulator was adapted to "learn" to detect and classify patterns in electronic signals generated by avionics gear used in aircraft. Through this classification, the system is able to convert the electronic signals into symbols for use by a computer program that can reason about the relationships between avionics signals. The artificial neural system or neural network was able to recognize selected patterns with 100 percent accuracy - establishing the feasibility of using this technology to convert signals into symbols. The research was conducted for the Sacramento Air Logistics Center, where the U.S. air force conducts tests to determine how modified avionics gear will perform in flight.

FOR ADDITIONAL INFORMATION: For more information, contact Marv Clement (509)375-2789.

NASA Tech Brief
National Aeronautics and Space Administration
Lewis Research Center, Cleveland, Ohio

Experimenting With Multiprocessor Simulator Concepts

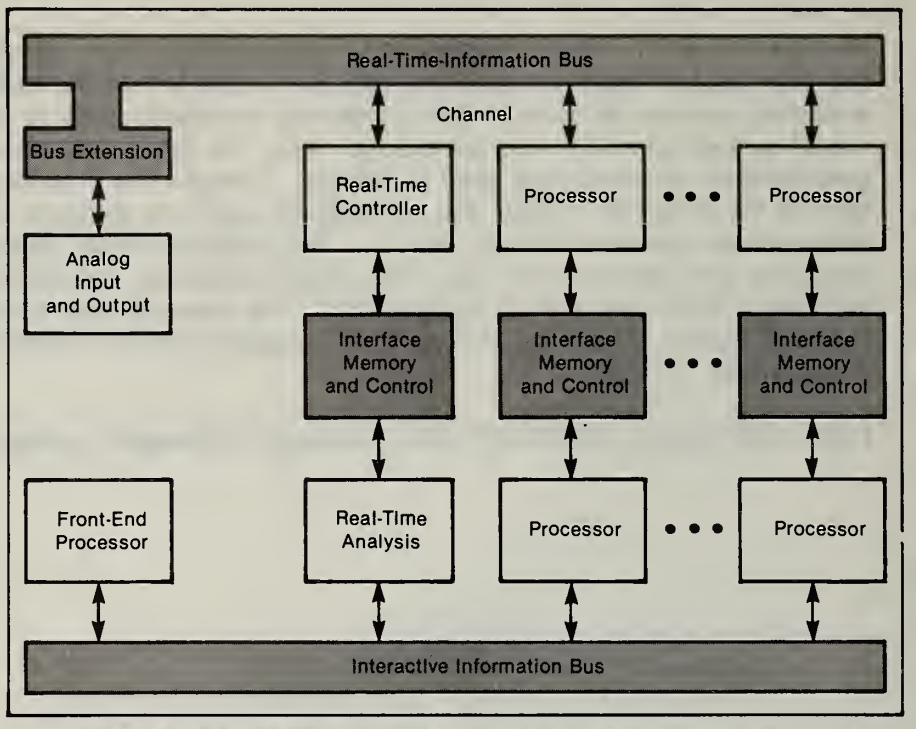
A system helps users develop equipment and programs.

A multiple microcomputer system is used to investigate the application of parallel processing to real-time simulation. The system, called the real-time multiprocessor simulator (RTMPS), is a tool for developing low-cost, portable, user-friendly simulators.

RTMPS includes off-the-shelf microcomputer boards and minimal custom interface circuitry to provide as many interprocessor communication paths as possible. This approach allows the emphasis to be placed on the development of software, which is a critical element in parallel processing. Among the software issues that RTMPS can address are high-level programming languages, scheduling the transfer of data between computers, the partitioning of programs, and support by an operating-system program.

The system can be based on a variety of microcomputer types. The characteristics of the hardware of each type are accounted for in a system executive program, a set of macroinstructions, and a target-computer-definition file. The system executive program performs such rudimentary functions as initialization, transfer of data, and handling of interruptions. The system macroinstructions define basic mathematical and data-transfer operations for the target hardware. The target-definition file provides information in high-order language about the microcomputer programming model. The system translates the high-order language into a time-efficient Assembler source program.

To retarget the system to a different microcomputer, changes are made only in the system executive program, the macroinstructions, and the target-computer-definition file. The bulk of the software remains unchanged.



With **Dual-Bus Architecture**, each microcomputer communicates with a corresponding microcomputer on the opposite bus through a dual-port interface memory. Transfers of data to and from the front-end processor occur on the interactive information bus. Transfers of data related to simulation calculations occur on the real-time-information bus.

The system is based on a dual-bus architecture with multiple microcomputers on each bus (see figure). The front-end processor is the main processor: It is the interface between the user and the system and handles such operations as the loading of programs into each of the simulation processors; control of modes of simulation; and the handling, output, and display of data. An analog input/output interface enables the connection of such devices as sensors, actuators, and analog computers.

This work was done by Richard A. Blech and Anthony D. Williams of **Lewis Research Center**. *Further information may be found in NASA TM-38802 [N86-28651/NSP], "Hardware Configuration for a Real-Time Multiprocessor Simulator."*

Copies may be purchased [prepayment required] from the National Technical Information Service, Springfield, Virginia 22161, Telephone No. (703) 487-4650. Rush orders may be placed for an extra fee by calling (800) 336-4700.

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NASA Tech Brief
National Aeronautics and Space Administration

Passivity in Analysis of Robustness of a Control System

A robustness margin (a measure of the degree of passivity) is defined.

A paper presents a new approach to the analysis of the stability of a multivariable feedforward-and-feedback control system that consists of an exponentially stable linear time-invariant (LTI) feedforward subsystem and a nonlinear time-varying (NTV) or a dynamic feedback subsystem. Whereas older methods of analysis are based on small-gain conditions (e.g., maximum and minimum singular conditions, H_∞ norm, and μ measure), the new method is based on the notion of passivity, which is quantified by a robustness margin. In effect, this margin provides a bound on the magnitudes of perturbations, below which the perturbations will not make the system unstable.

The feedforward subsystem is assumed given, and the problem is to characterize a class of feedback subsystems that preserve the exponential stability of the system. By finding as large a stability region as possible under the nominal control, the controller can be tuned to enhance the robustness margin by effectively moving the nominal feedback system to a different point.

The measures of robustness used in the small-gain methods involve only the magnitude (but not the phase) information of the feedforward subsystem. Based on experience in the design and analysis of classical compensators, it is known that the phase of the nominal controlled system is frequently of critical importance. Ignoring this information can sometimes lead to conservative design. The argument of passivity is motivated by this observation.

The characterization of robustness involves the Hermitian part of a transfer function, which contains both the gain and phase information. The importance of passivity lies in the concept of energy. The condition for the stability of the system can be stated as follows: If energy generated by one block can be dissipated by the other block, the system is stable. The amount of energy generated or dissipated by a system is characterized by a quantity called the ν index, which is a measure of the minimum amount of parallel dissipation required to render a system passive. This energy-transfer perspective is powerful because nonlinear systems can be considered within the same context. Thus, hitherto inadmissible perturbations like saturation of actuators, coulomb friction, stiction, and hysteresis can all be analyzed.

Three classes of perturbations are considered: memoryless, NTV, exponentially stable LTI, and general nonlinear dynamic. The theoretical basis of the stability condition is on the theorem of absolute stability for the first class of perturbations and the theorem of hyperstability for the latter two. These perturbations are represented in terms of a lower bound involving an inner product and an upper bound on the norm. The stability condition then shows tradeoffs between the two bounds. When only the bound on the norm is imposed, the H_∞ stability criterion is recovered. Because the Lyapunov technique is used rather than the multivariable Nyquist theorem, nonlinear perturbations (both memoryless and dynamic) are permitted. For nonlinear dynamic systems, the small-gain condition involves truncated L_2 norms.

When the perturbation is characterized by a matrix that contains additional block diagonal structure, a robustness margin is derived for each block. The derivation is based on the generalization of the Gorshgorin theorem to block-diagonal matrices. If each of the diagonal blocks is of size one, then a margin for positive and negative variations of each diagonal element can be obtained by repeated application of the passivity argument to the feedforward subsystem with signs of some of its columns and rows reversed. An upper bound for the μ measure is easily computed by use of the same analysis.

This work was done by John Ting-Yung Wen of Caltech for **NASA's Jet Propulsion Laboratory.** *"Robustness Analysis Based Passivity." NPO-17589/TN*

FOR ADDITIONAL INFORMATION: *Contact: Director, Technology Transfer Division, P.O. Box 8757, BWI Airport, MD 21240; (301) 621-0100 Ext. 241*
REFER TO THE NUMBER LISTED AT THE END OF THIS ARTICLE

Data-Dictionary-Editing Program

Access to data-dictionary relations and attributes is made more convenient.

The Data Dictionary Editor (DDE) computer program was developed to give the developers of data bases more convenient access to the OMNIBASE VAX/IDM data-dictionary relations and attributes. Prior to the development of DDE, access to the descriptions table could be obtained via OMNIBASE IQL software. However, it was necessary to specify relations (tables) and attributes (fields) by numbers associated with their names. The DDE application program provides more convenient read/write access to the data-dictionary table ("descriptions table") via a data screen that uses SMARTQUERY function keys. (SMARTQUERY is an OMNIBASE software product that uses special function keys for the storage and retrieval of data records.)

DDE provides three main advantages: (1) The user works with the table names and field names rather than with table numbers and field numbers, (2) DDE provides online access to definitions of data-dictionary keys, and (3) DDE provides a displayed summary list that shows, for each datum, which data-dictionary entries currently exist for any specific relation or attribute.

The DDE data screen is an OMNIBASE SMARTDESIGN screen with two windows. The top window retrieves relation (table) descriptions and attribute (field) descriptions. The bottom window retrieves definitions of data-dictionary keys. DDE allows users to switch back and forth between the two windows without interfering with retrievals in progress in either window.

The DDE application program was developed for specific use: that of review and editing of records in the OMNIBASE "descriptions" relation (table). However, the routines that allow more than one retrieval sequence to be in progress at the same time can be adapted for use in other OMNIBASE applications.

DDE was developed on a DEC VAX 750 computer under VMS 3.6. Implementation of DDE requires a Brittain Lee data-base machine with IDM 500 and the OMNIBASE software package. OMNIBASE is available from Signal Technology, Inc. The DDE program was developed in 1987.

This program was written by A. P. Cumming of McDonnell Douglas Corp. for **Johnson Space Center.**
MSC-21290/TN

FOR ADDITIONAL INFORMATION

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Electrotechnology

0938 Barium-Dispenser Thermionic Cathode—Features include long operating life and high current density.

0939 Composite Semiconductor Substrates—Layered structures pave the way for monolithic imaging devices.

0940 Fast Correction for Doppler in MDPSK Signals—Open-loop estimation of frequency and differential detection are combined. (Licensing Opportunity)

0941 Computing Resonances of Wavegudie-to-Microstrip Transitions—Trial-and-error design procedures are no longer necessary.

0942 Improved Coplanar Waveguides—Features include less attenuation and looser tolerances.

0943 Metal Coat Increases Output Sensitivity—Quantum efficiency, charge-collection efficiency, and low read noise are optimized. (Licensing Opportunity)

0944 Some Protocols for Optical-Fiber Digital Communications—One words best in heavy traffic; another, in light traffic.

Testing & Instrumentation

0945 Determination of Astroposition

0946 Microtronic Flow Transducer—This device is much smaller and more sensitive than existing flowmeters.

Other Items of Interest

0980 Molecular-Beam Epitaxy of $CrSI_2$ on Si(111)—Crystalline layers have been grown in a commercial apparatus.

NASA Tech Brief
National Aeronautics and Space Administration
Lewis Research Center, Cleveland, Ohio

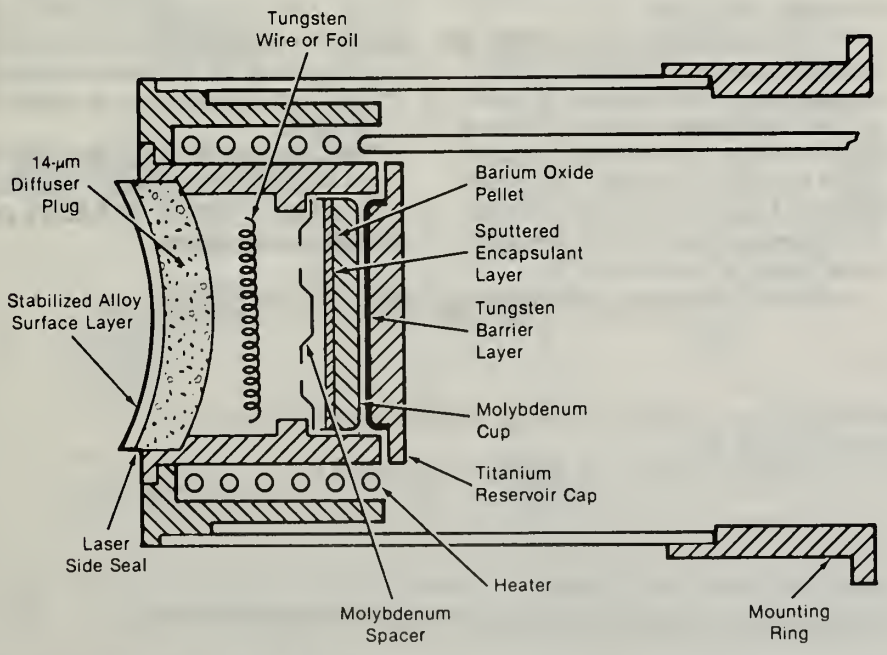
Barium-Dispenser Thermionic Cathode

Features include long operating life and high current density.

An improved reservoir cathode serves as an intense source of electrons required for high-frequency and often high-output-power, linear-beam tubes, for which long operating lifetime is an important consideration. The continuing development of millimeter-wave tubes capable of powers of hundreds to thousands of watts for applications in space communications and in high-resolution radar systems has created a large and growing demand for thermionic cathodes capable of fully-space-charge-limited (FSCL) emission-current densities of 4 A/cm^2 or more.

These high current densities are needed for higher beam currents, smaller beam sizes, and better focusing of beams, and because of practical limitations on the convergence of beams in electron guns. Gridded gun structures demand the capability for current densities that are even greater — by as much as a factor of 2. Because of the very high costs of high-performance tubes and the systems in which they operate, long-life operation and reliability of cathodes are obviously of great importance.

Barium-dispenser thermionic cathodes, in particular the Ba-impregnated type, are most commonly used in tubes for space-communication and radar applications. Barium is essential to reduce the work functions of the emitting surfaces sufficiently for useful levels of thermionic emission at temperatures of the order of 1,000 °C. During the operation of a cathode, Ba is continuously lost through evaporation and must be replenished to maintain high emission. The lifetime of a cathode is thus critically dependent upon the availability of Ba.



The Improved Reservoir Cathode stores Ba in the form of BaO to replenish the Ba lost from the emitting surface. (The Ba lowers the electron work function to enhance thermionic emission.)

The improved reservoir cathode, shown schematically in the figure, was initially developed for continuous operation at emission-current densities in the range of 4 to 10 A/cm^2 for 100,000 hours or more. High emission-current densities are obtained through the use of an emitting surface of relatively-low effective work function and narrow work-function distribution, consisting of a coat of W/Os deposited by sputtering. Lower operating temperatures and enhanced electron emission are consequently possible.

In addition, a segregated-grain-size W powder is used for the porous Ba-vapor-diffuser plug to control the flow and allow adequate amounts of Ba to reach the surface with no need for cathode temperatures higher than required for the desired level of emission current. Long operating life is achieved by using a reservoir of BaO to store the Ba. The advantage of this approach is a constant rate of supply of Ba until practically the entire amount of Ba in the reservoir, which can be quite large, is exhausted. Also contributing to longer life is the stabilization of the W/Os composition of the emitting surface by means of a W/Os diffusion barrier formed in the underlying W matrix by an Os-chemical-infiltration technique.

In emission tests of the improved reservoir cathode, FSCL current densities of as much as 16 A/cm^2 have been obtained. The W/Os alloy surface has been demonstrated to be capable of more than 50 A/cm^2. Although originally developed to span a smaller range, the effective range of current densities for the cathode is 1 to 50 A/cm^2 and possibly as high as 100 A/cm^2. It is possible to store enough Ba (about 0.5 g) in the reservoir to endure about 100,000 hours of operation at this current density or less time at greater current densities.

This work was done by Edwin G. Wintucky of **Lewis Research Center** *and M. Green and M. Feinleib of Varian Associates, Inc. No further documentation is available.*
LEW-14685/TN

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NASA Tech Brief
National Aeronautics and Space Administration
NASA's Jet Propulsion Laboratory, Pasadena, California

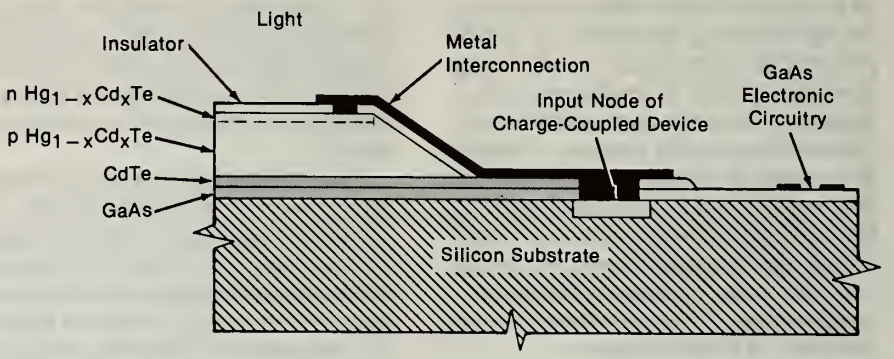
Composite Semiconductor Substrates

Layered structures pave the way for monolithic imaging devices.

An epitaxial structure of three semiconductor materials — silicon, gallium arsenide, and cadmium telluride — may make possible integrated monolithic focal-plane arrays of photodetectors. The silicon layer would contain charge-coupled devices, the gallium arsenide layer would contain other fast electronic circuitry, and the cadmium telluride layer would serve as the base for an array of mercury cadmium telluride infrared sensors (see figure).

Currently, focal-plane arrays are made by hybrid technology. The various semiconductor components are bonded to substrates and interconnected. For example, an HgCdTe array of photodiodes can be stacked on a silicon array of charge-coupled devices by joining the two arrays via indium contact bumps. A monolithic array would be more reliable and manufacturable and could contain smaller, more closely spaced elements for higher resolution of the image.

The present work describes how CdTe was grown on GaAs/Si substrates. Both the <100> and <111> orientations of the substrates were used. This new growth technique effectively combines two well-established techniques; namely, metalorganic chemical-vapor deposition (MOCVD) and molecular-beam epitaxy (MBE). CdTe is grown via MOCVD, which results in a highly-efficient throughput, low-cost production of this material. GaAs is initially grown on Si by MBE, a process featuring very precise nucleation for obtaining device-quality GaAs on Si.



A **Multilayer Structure** would include HgCdTe light sensors with Si readout devices and GaAs signal-processing circuits. A CdTe layer would provide a base for building up the HgCdTe layer.

An initial degreasing of the Si wafers is followed by a series of oxidation and oxide-removal steps. Oxide-covered Si wafers are then spin-etched to remove the oxide inside a nitrogen glove box and then transferred by load-lock into the MBE-growth chamber. A slow growth of GaAs at the rate of 0.1 monolayer/s at 400 °C is followed by faster growth at 1 μm/h at 580 °C.

In the MOCVD process, CdTe epilayers having very specular mirrorlike surfaces are grown on the above MBE-grown samples of GaAs/Si. Growth is conducted at atmospheric pressure in a horizontal quartz reactor with an RF-heated graphite susceptor. The metalorganics are transported into the reactor by palladium-purified hydrogen, and preliminary runs are conducted at 400 °C.

This work was done by Akbar Nouhi, Gouri Radhakrishnan, Joseph Katz, and Kris Koliwad of Caltech for **NASA's Jet Propulsion Laboratory**.

NPO-17342/TN

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NASA Tech Brief
National Aeronautics and Space Administration
NASA's Jet Propulsion Laboratory, Pasadena, California

Licensing Opportunity

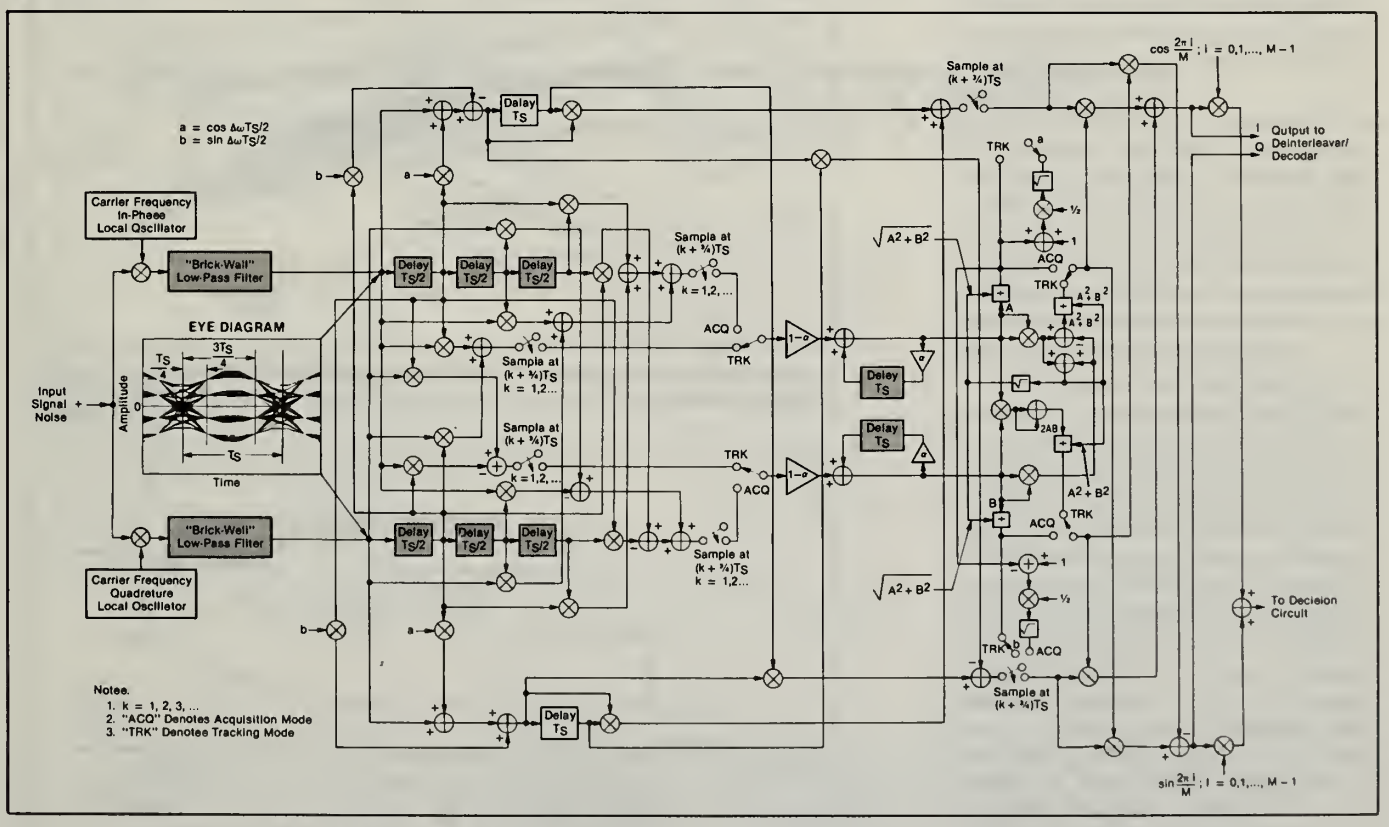
Fast Correction for Doppler in MDPSK Signals

Open-loop estimation of frequency and differential detection are combined.

A detector of multiple differential phase-shift-keyed (MDPSK) signals is being designed to effect a combination of open-loop estimation of frequency and differential detection of digital modulation. The improved design is expected to decrease the probability of bit errors in situations in which the carrier frequency is uncertain and signals are transmitted in bursts that are too short to allow closed-loop tracking of the carrier frequency — for example, in the transmission of digitally-coded voice signals in land-mobile/satellite communications at ultra-high frequencies.

The design of the detector is based in part on the fact that whereas the change in phase of the received signal during a full symbol period contains the sum of the data phase and the Doppler-induced phase shift, the change in phase during half a symbol period within a given symbol interval contains only the Doppler-induced phase shift. Thus, by a combination of full-symbol and half-symbol differential detection together with suitable processing (including postdetection integration), the Doppler component can be estimated and removed.

The figure illustrates a baseband version for the detection of 8DPSK signals. The Doppler shift is estimated in two modes: acquisition and tracking. In the tracking mode, the estimate is updated repeatedly in the presence of the input 8PSK data signal. Samples are taken at the $3T_S/4$ point in each symbol period T_S. The samples reflect multiplications of the in-phase (I) and quadrature (Q) values of signal plus noise at $T_S/4$ and $3T_S/4$. In principle, the means of the I and Q samples are proportional to the cosine and sine, respectively, of the Doppler component of the phase shift during half a symbol period, and this would enable



This **8DPSK Differential Detector** operates in a tracking or an acquisition mode to correct for Doppler shifts.

the calculation of the Doppler component.

The problem of estimation is complicated somewhat when the data pulses are not rectangular. However, if the pulses are shaped by raised-root-cosine filtering at the transmitter and "brick-wall" low-pass filtering at the receiver, the sine and cosine conditions are still met at the $T_S/4$ and $3T_S/4$ points, enabling the estimate to be made.

In addition, a normalizing gain of $1-\alpha$ at the input to the sample accumulator and a gain of α in the feedback path cause the system to weigh the most recent samples most heavily and to give exponentially decaying weight to previous samples.

To remove the Doppler component from the I and Q samples used to detect data, it is necessary to compute

$$\cos\left[2\tan^{-1}(B/A)\right] = \frac{A^2-B^2}{A^2+B^2}$$

and

$$\sin\left[2\tan^{-1}(B/A)\right] = \frac{2AB}{A^2+B^2}$$

where A and B are the outputs of the sample accumulators as indicated in the figure.

Ordinarily, the I and Q samples used to detect data would be taken at the middle

($T_S/2$) of each symbol period. To recover a 3-dB loss in the signal-to-noise ratio due to sampling at the $T_S/4$ and $3T_S/4$ points and shaping of the pulse, the samples are weighted by *a* and *b* (see figure) and added in the data-detecting section before differential detection.

In the acquisition mode, a known sequence of data symbols — for example, all zeros — is transmitted. Thus, the change in modulation phase is known (e.g., zero) during a symbol period, and one can use the data-detection samples to estimate the Doppler component of phase shift. Also, because these samples are proportional to the cosine and sine of the Doppler component of the phase shift during T_S (rather than $T_S/2$), the outputs of the accumulators can be used directly to remove the Doppler component from the data-detection samples.

The processing of the outputs of the detector depends on whether the modulation contains uncoded or coded data. In the case of uncoded data, one simply makes decisions on the detector outputs in the same manner as in a conventional (not Doppler-corrected) MDPSK receiver. For coded transmission, the detector outputs are quantized to implement the soft-decision decoding metric.

This work was done by M. K. Simon and D. Divsalar of Caltech for **NASA's Jet Propulsion Laboratory**.

This invention is owned by NASA, and a patent application has been filed. Inquiries concerning nonexclusive or exclusive license for its commercial development should be addressed to the Patent Counsel, NASA's Resident Office-JPL
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NASA Tech Brief
National Aeronautics and Space Administration
Lewis Research Center, Cleveland, Ohio

Computing Resonances of Waveguide-to-Microstrip Transitions

Trial-and-error design procedures are no longer necessary.

A simplified mathematical model can be used to predict the resonant frequencies of antipodal-finline waveguide-to-microstrip transitions. There is an increasing need for such transitions and the mathematical tools to design them because the trend in microwave integrated circuits is to use microstrip connections, but low-loss transmission lines and test equipment for millimeter wavelengths require rectangular waveguides.

Previous design rules did not address directly the resonant frequencies of transitions, which had to be found by trial and error and which must be placed outside the frequency bands of the devices to which they are connected. The new model makes it possible to place the undesired resonances outside the desired frequency band during the design process; this will eliminate much of the iteration in the design process and thereby reduce both the time and the cost of design.

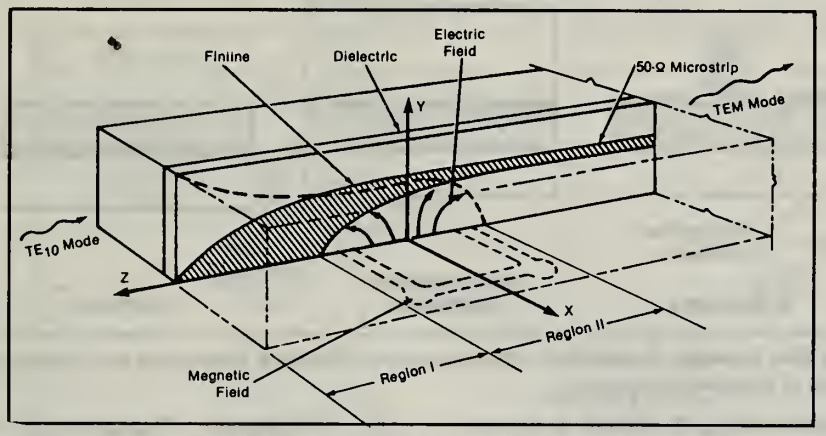

Figure 1. An **Antipodal-Finline Waveguide-to-Microstrip Transition** transforms the incoming high-impedance TE_{10} waveguide electromagnetic mode to the low-impedance outgoing stripline mode.

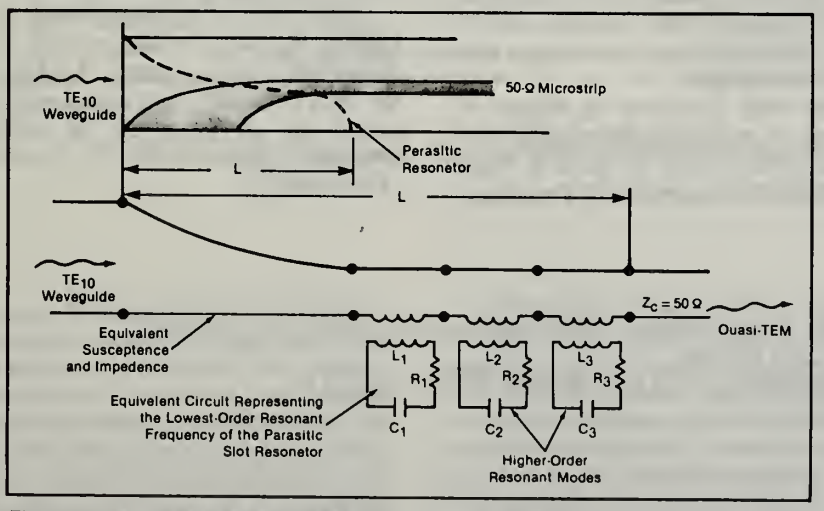

Figure 2. This **Lumped-Element Model** gives good approximations for the resonances of the waveguide-to-microstrip transition.

In region I of the transition (see Figure 1), the tapered antipodal finline concentrates the electric field and rotates it 90° from the incident TE_{10} waveguide mode to the quasi-microstrip mode. The high impedance of the TE_{10} waveguide mode is transformed to a lower impedance — usually about 50 Ω — typical of microstrip transmission lines. In region II the transformation continues from the finline to the stripline mode. The waveguide-to-finline interface and the discontinuities of the finline create evanescent modes in region II that give rise to the resonances.

The model is based on diagrams of the electromagnetic field and on experimentally derived parameters. A tapered transmission line is considered to be in series with an infinite set of coupled resonant circuits (see Figure 2). Each resonant circuit is treated as a resonance of a microwave resonant cavity, of which the resonant frequencies can be determined easily.

The success of the model depends on the choice of a model cavity and an effective permittivity that makes the resonances of the cavity coincide with the experimental values. In many practical cases, the need is met by a model of a cylindrical cavity filled with a material, the permittivity of which depends on the length of region II but is nearly independent of the frequency.

This work was done by George E. Ponchak and Alan N. Downey of **Lewis Research Center**. *Further information may be found in NASA TM-88905 [N87-16958/NSP], Price Code: A02 "A New Model for Broadband Waveguide to Microstrip Transition Design."*

Copies may be purchased from the National Technical Information Service, Springfield, Virginia 22161, Telephone No. (703) 487-4650. Rush orders may be placed for an extra fee by calling (800) 336-4700.
LEW-14637/TN

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NASA Tech Brief
National Aeronautics and Space Administration
Lewis Research Center, Cleveland, Ohio

Improved Coplanar Waveguides

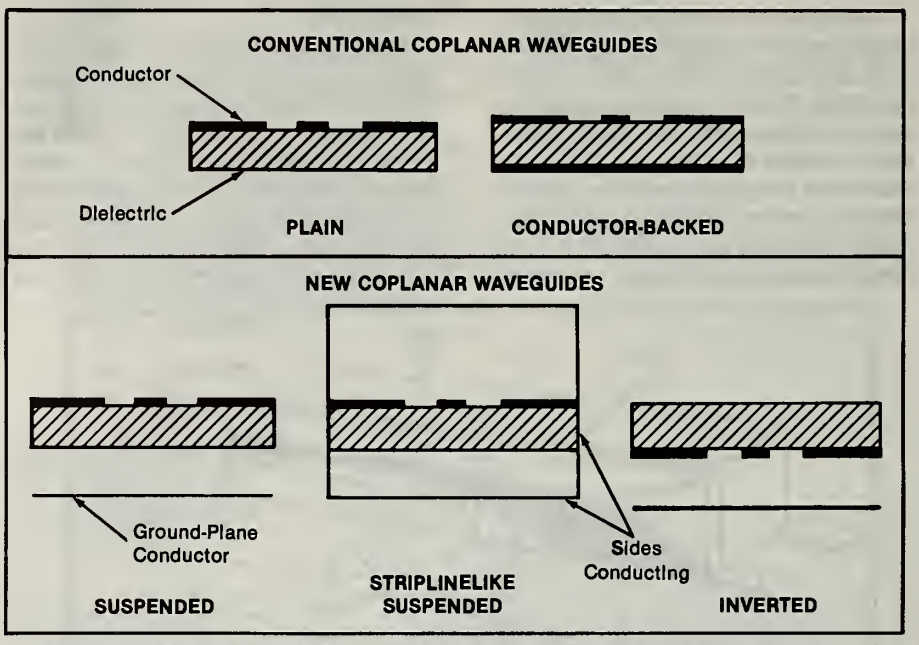
Features include less attenuation and looser tolerances.

Three new types of coplanar waveguide transmission lines have been proposed: suspended, striplinelike suspended, and inverted. Numerical analyses of the propagation of the electromagnetic fields of the new and of the more-conventional plain and conductor-backed coplanar waveguides showed that the new waveguides offered several advantages over the conventional ones.

The ratios of the guide wavelengths to the free-space wavelengths in the new waveguides are closer to 1 so that the dimensions are larger and the tolerances correspondingly looser. The effective dielectric constants are lower, signifying that the electromagnetic-field energies are concentrated more in the air regions and less in the dielectrics; consequently, attenuation, which is due in part to losses in dielectrics, should be reduced.

For specified identical characteristic impedances and specified identical widths of strips, the new configurations have wider slots. Thus, low-impedance transmission lines can be realized with wider (therefore, easier-to-make) slots.

In an inverted coplanar waveguide, such active devices as Gunn and impact-avalanche-and-transit-time diodes can be mounted between the strip conductor and the metal trough. The metal trough also acts as an efficient heat sink. An electric-field-plane probe-type transition between a rectangular waveguide and a suspended coplanar waveguide can be constructed. This feature should have many uses in the testing of planar active devices and circuits like GaAs metal/semiconductor field-effect transistors and monolithic microwave integrated circuits operating at millimeter wavelengths.



Three **New Coplanar Waveguide** configurations promise lower attenuation and reduce the effects of manufacturing errors.

This work was done by Rainee N. Simons of **Lewis Research Center**. *Further information may be found in NASA TM-89839 [N87-20469/NSP], Price Code: A02 "Propagation Characteristics of Some Novel Coplanar Waveguide Transmission Lines on GaAs at MM-Wave Frequencies."*

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NASA Tech Brief
National Aeronautics and Space Administration
NASA's Jet Propulsion Laboratory, Pasadena, California

Licensing Opportunity

Metal Coat Increases Output Sensitivity

Quantum efficiency, charge-collection efficiency, and low read noise are optimized.

A charge-coupled photodetector (see Figure 1) has been optimized for maximum quantum efficiency (QE), high charge-collection efficiency, and ultralow read noise. Called a "flash-coupled" photodetector, the sensor delivers high quantum-efficiency sensitivity in the spectral range extending from the soft x ray to the near infrared (1 to 11,000 Å.

The detector incorporates a "flash-gate," which is a sparse (less than a monolayer) surface deposit of metal that has a high work function relative to the substrate of the sensor. The flashgate creates an electric field greater than 10^5 V/cm that

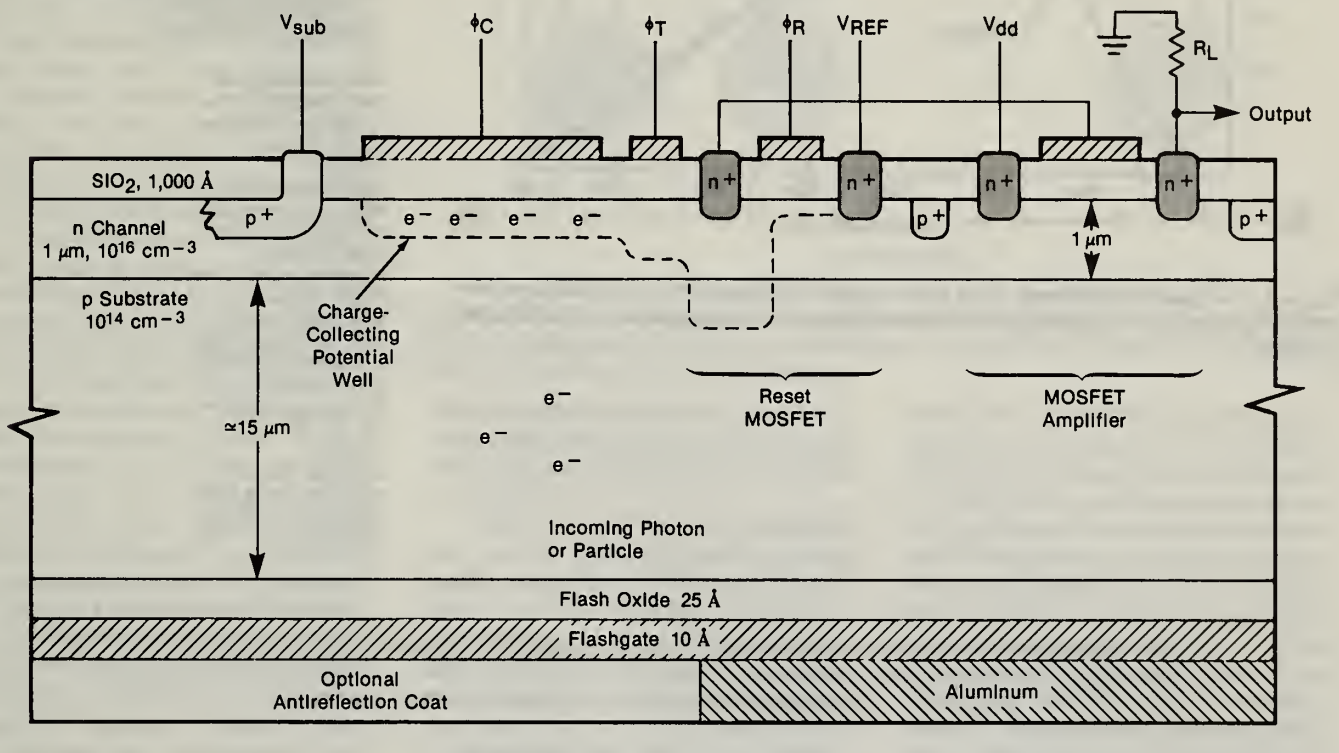

Figure 1. The **Flash-Coupled Photodetector** combines high quantum efficiency, charge-collection efficiency, and ultralow read noise.

sweeps photogenerated electrons from the surface, where they would otherwise be lost to recombination. The collecting electrode (ϕ_C) shown in Figure 1 is biased positively and forms a depletion region that extends completely to the surface, establishing an electric field throughout the entire photosensitive volume of the detector. As a result of these two fields, the sensor exhibits 100 percent internal charge-collection efficiency and high overall quantum efficiency (see Figure 2).

Once a packet of signal electrons is collected, it is transferred through a transfer gate (ϕ_T) to a sense node that is connected to a high-performance metal-oxide/semiconductor field-effect-transistor (MOSFET) amplifier. The MOSFET is designed to deliver maximum conversion sensitivity (i.e., high volts/electron) in conjunction with low 1/f and white-noise characteristics, where noise levels of less than 2 e^- rms have been recently achieved. Low-noise performance in combination with high-collection capacity of the collecting electrode (several millions of electrons) produces a sensor with ultrahigh dynamic range in excess of 1,000,000.

After signal charge is read out, the sense node is reset (ϕ_R) by a reset MOSFET shown in Figure 1, preparing the sense node for a new charge packet. The flash-coupled photodetector is configured so that either a readout of the signal charge can take place while charge is being collected or the detector can be sampled continuously, depending on application.

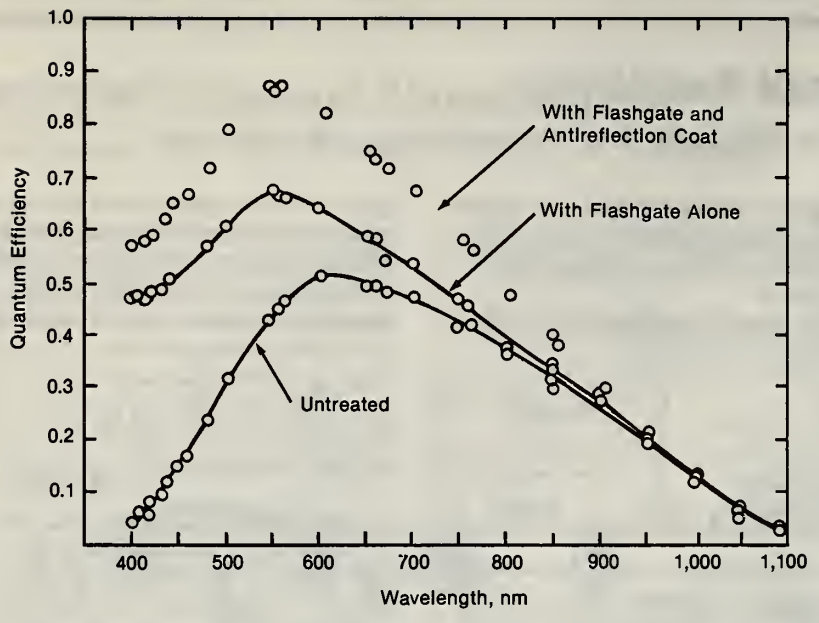

Figure 2. The **Quantum Efficiency** of the flash-coupled photodetector in the visible and near-infrared spectral region is enhanced by the flashgate and increased further by an antireflection coat.

This work was done by James R. Janesick of Caltech for **NASA's Jet Propulsion Laboratory.**

In accordance with Public Law 96-517, the contractor has elected to retain title to this invention. Inquiries concerning rights for its commercial use should be addressed to

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NASA Tech Brief
National Aeronautics and Space Administration
NASA's Jet Propulsion Laboratory, Pasadena, California

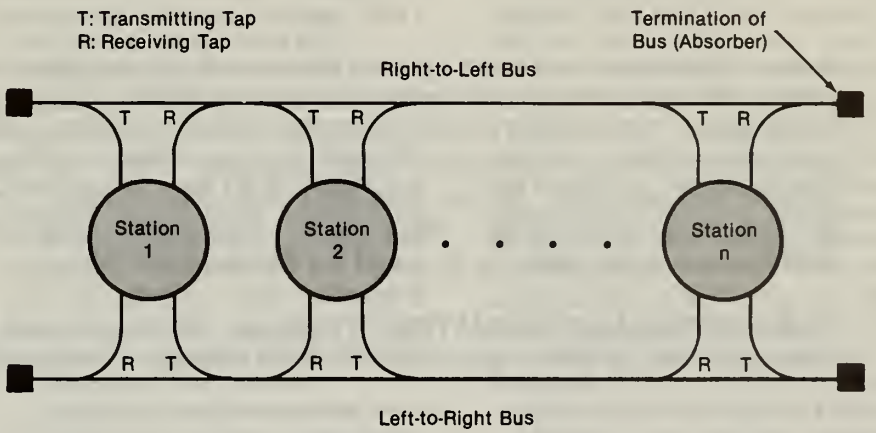
Some Protocols for Optical-Fiber Digital Communications

One works best in heavy traffic; another, in light traffic.

Three protocols have been proposed for digital communications among stations connected by passive taps to a pair of unidirectional optical-fiber buses. The protocols mediate round-robin, bounded-delay access to the buses by all stations and are particularly suited to fast transmission. Partly because the transmission medium is passive (there are no relay stations) and partly because the protocols distribute the control of the network among all stations with provision for the addition and deletion of stations (there are no control stations), the communication network should be able to resist and recover from failures.

The signals on the two buses travel in opposite directions. Each station includes a transmitter and receiver connected to both buses (see figure). When the receiver detects a carrier signal, it attempts to synchronize itself to the bits in the preamble of the incoming signal and to copy the signal into the memory of the station. Provided that the receiver detects no signal coming from upstream and/or has been granted access by the protocol, the transmitter sends a preamble followed by a packet of data. There is a delay between the time a station senses the end of a carrier on a bus and the time when it can start transmitting on the same bus. There is an equal delay between the sensing of a carrier coming from upstream and the interruption of a transmission. These functions are common to all unidirectional-bus systems but are managed in different ways by different protocols.

The first of these three protocols, called "U-Net," defines a procedure to determine which two stations are at the right and left ends of the bus and which should transmit a special sequence of bits called the "token." The network then operates in cycles that are initiated when the left-end or right-end station transmits the token. Each station downstream from the initiating end station waits for the token and any appended packets of data to pass by,



Traffic on the Twin Unidirectional Buses is managed by any of three protocols described in the text. Each has advantages and disadvantages, depending on the level of traffic and the number of stations attempting to transmit.

then transmits its own packet (if any). Thus, each station has an opportunity to add a packet of data to a train of packets headed by the token.

When traffic is light or only one station has data to send, the U-Net protocol wastes time by forcing the transmitting station to wait for the token and then to transmit only one packet at each pass. This disadvantage is overcome by a hybrid protocol that enforces a random-access mode when traffic is light or a single station is transmitting and reverts to an implicit-token mode when multiple-source traffic builds up. This protocol is called "Buzz-Net" because of a buzzing signal that any station transmits to synchronize the network and drive it to the token mode under certain conditions of increasing traffic.

While the Buzz-Net protocol is efficient at low traffic, it is less efficient than the U-Net protocol is at high traffic, where it wastes time by repeatedly switching between the two modes. The "Token-less" protocol was introduced to obtain efficiency at high traffic, to reduce waiting at low traffic, and to eliminate special token-initialization procedures. As the name implies, this protocol does not involve an explicit token. Instead, it supports a round-robin access mode like that of U-Net, and the synchronizing event (implicit token) is the cessation of activity on one of the buses. The implicit token propagates in one direction on one bus and in the opposite direction on the other bus, thus minimizing the interval of silence between the end of one round and the beginning of the next.

This work was done by Cavour Yeh and Mario Gerla of the University of California for **NASA's Jet Propulsion Laboratory.** *NPO-17333/TN*

FOR ADDITIONAL INFORMATION: *Contact: Director, Technology Transfer Division, P.O. Box 8757, BWI Airport, MD 21240; (301) 621-0100 Ext. 241*
REFER TO THE NUMBER LISTED AT THE END OF THIS ARTICLE

U.S. Army Corps of Engineers
Engineer Topographic Laboratories
Fort Belvoir, VA 22060-5546

Determination of Astroposition

A new instrument developed by the U.S. Army Engineer Topographic Laboratories provides precise time and accurate measurements from star transits for accurate and precise astronomic longitude termination. The optical micrometer of a meridian circle or theodolite is replaced with a square photosensor array. Comprising many precisely positioned, highly miniaturized photosensors, the array is self-scanning. When used with dedicated circuitry, it measures and tracks the position of the star image on the array. Since the star's image is focused at a location on the surface of the photosensor array, there is no need for direct observation.

FOR ADDITIONAL INFORMATION: To discuss this effort further, contact: George Simcox, U.S. Army Engineer Topographic Laboratories, Fort Belvoir, VA 22060-5546; (202)355-2629.

NASA Tech Brief
National Aeronautics and Space Administration
Lewis Research Center, Cleveland, Ohio

Microtronic Flow Transducer

This device is much smaller and more sensitive than existing flowmeters.

As an outgrowth of work sponsored by the NASA Lewis Research Center on research on deep impurities in silicon, a novel microelectronic airflow and gas-flow transducer has been developed. Unlike other gas-flow meters and transducers, this device has no moving parts and can be constructed by use of a variation on the ordinary technology for the processing of planar silicon microelectronics, where hundreds or indeed thousands of these identical devices can be concurrently produced on a single chip as easily as can one.

This device is fundamentally a Wheatstone-bridge semiconductor version of a hot-wire anemometer. The four legs of the Wheatstone bridge are identical silicon resistors, etched out of a solid single-crystal wafer (see Figures 1 and 2). Regardless of the ambient temperature, the bridge remains in balance, and its output voltage is zero unless air or gas flows across it. In the latter event, the flow cools the legs perpendicular to the flow more strongly than it cools the legs parallel to the flow.

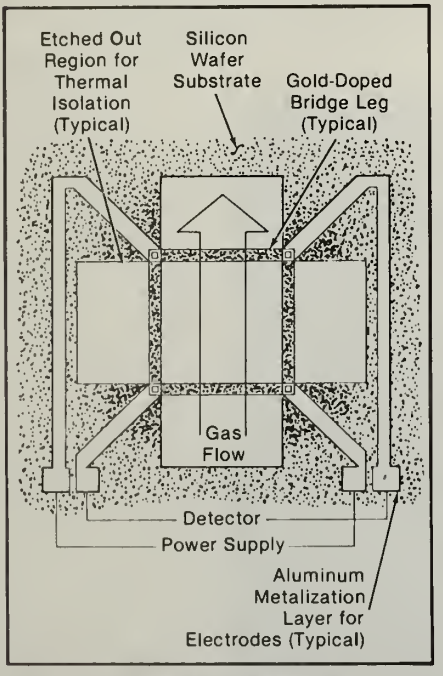


Figure 1. The **Gas-Flow Transducer** is based upon an integrated Wheatstone bridge in a silicon chip. The legs are doped with gold and isolated thermally by etching away the surrounding material (except the corners).

Although the size of the device is in the range of 40 to 80 mils (1 to 2 mm) [because it is etched through a conventional 10-mil (0.25-mm) positively-doped metal-oxide/semiconductor wafer], in an epitaxial configuration the size can be reduced to the range of the thickness of the epitaxial layer. Techniques have been developed to etch away the substrate under the epitaxial layer and stop the anisotropic etching process at the interface between the epitaxial layer and the substrate.

This miniature electronic device, which provides a direct, sensitive voltage indication of flow, can easily be connected to simple digital or analog metering (often without supplementary electronics), or the signal can be used to activate other controls. However, because the device is fabricated on a conventional silicon wafer, auxiliary electronics and signal processing can be done on the circuit chip if desired. The sensitivity and range can be adjusted by adjusting the power-supply voltage and, therefore, the heating of the bridge legs. The sensitivities to flow that have been measured in the laboratory, even with a crude version of the device, exceed the sensitivity of any known commercial flowmeter.

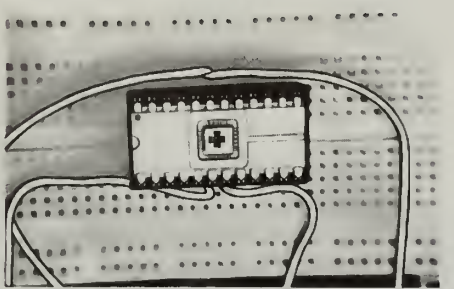


Figure 2. An **Integrated Circuit** contains a transducer like the one shown schematically in Figure 1.

The new microtronic mass-flow transducer has many potential advantages over present hot-wire anemometers, which are mainly reserved for specialized laboratory studies because they are so fragile and easily affected by contamination. The new transducer has a calculated sensitivity at least 100 times as high and a size 100 times as small. It can be passivated with either silicon dioxide, diamondlike films, or organic materials like parylene that form monolayers. Because of the high resistivity and sensitivity of the deep-impurity-doped silicon and the uniformity of single crystals, the new transducer is relatively insensitive to variations in temperature or pressure. It can be mounted in such a way as to make it reasonably rugged with regard to localized flows. In production quantities, the transducers (without ancillary processing electronics) should cost less than $1 apiece.

Because of the small size, sensitivity, and good directional capability of the new transducer, there are numerous potential applications in the measurement of vortexes, flows in inlets to pipes, and other complicated flows. It might be possible to build such planar devices directly into turbine blades or into the surfaces of aircraft to measure both magnitudes and directions of airflow.

The impetus for the device was the need for an electronic monitor to measure the postoperation breathing exercises of patients and prevent pneumonia. With associated electronics, the transducer could be used to provide information on lung function, or on the total intake of oxygen during a specified interval, or to sound an alarm. The transducer may lend itself to the more accurate monitoring and control of anesthetic gases during surgery. Another medical application would be to monitor the breathing patterns and to control the rate of flow of oxygen for premature infants.

This work was done by Gale R. Sundberg of **Lewis Research Center** *and H. T. Henderson and M. Walter Hsieh of the University of Cincinnati.* *LEW-14654/TN*

FOR ADDITIONAL INFORMATION: *Contact: Director, Technology Transfer Division, P.O. Box 8757, BWI Airport, MD 21240; (301) 621-0100 Ext. 241*
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Energy

0947 Grow-Your-Own Diesel Fuel Not Forgotten

0948 Optimized Wind Turbine Blades

0949 Microalgae Consume Greenhouse Gases While Producing Fuel

0950 Rapid Process Makes Energy-Smart Windows

0951 Advanced Small Rechargeable Batteries—Lithium-based units may offer the highest performance.

Other Items of Interest

0955 Handbook of Biomass Downdraft Gasifier Engine Systems

0974 Laser-Driven Process Etches Chemically Resistant Surfaces

0975 Sunlight Destroys Hazardous Waste

0992 Hot Electrons Could Improve Photoelectrochemical Cell Efficiencies

Research Technology
Agricultural Research Service
U.S. Department of Agriculture

Grow-Your-Own Diesel Fuel Not Forgotten

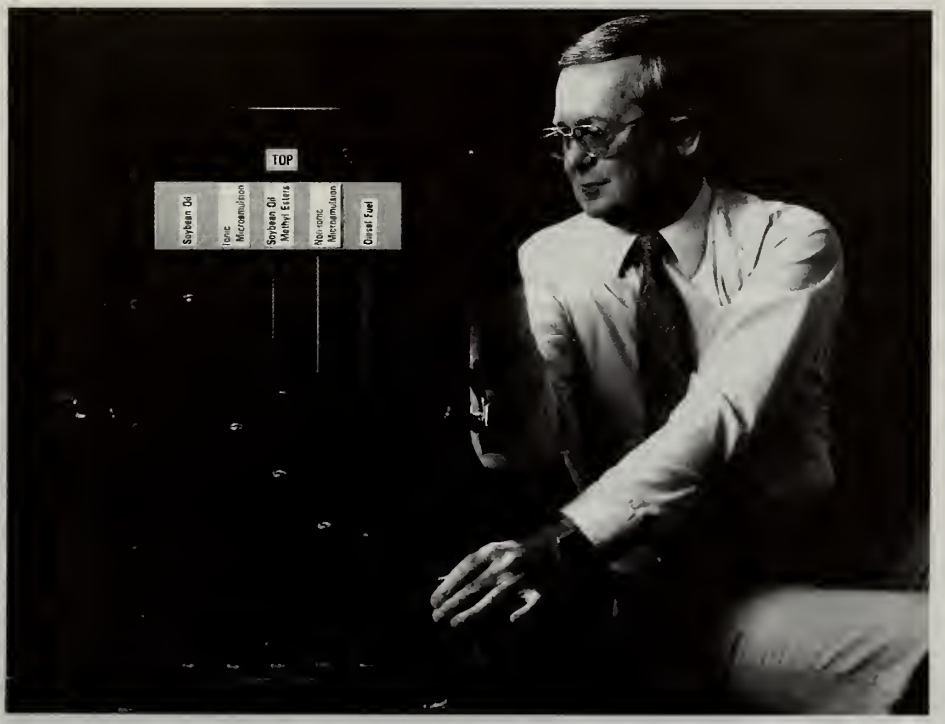
In the event of future petroleum shortages, such as that during the oil embargo of the 1970's, America's farm tractors could continue to roll during critical times of planting and harvest. That is not due to emergency stockpiles of diesel fuel, but rather to vegetable oils researchers are studying as alternative fuel sources.

"I'm not sure when vegetable oils will be economical enough to compete with petroleum-based fuels," says Agricultural Research Service organic chemist Marvin O. Bagby. "But, at the very least, we want to have something available to us in the event of an energy emergency."

Regional Research Center in Peoria, Illinois, says one problem researchers are facing is that the viscosity of most vegetable oils is about 15 times that of diesel fuel, which makes difficult injecting and atomizing the product into combustion chambers.

Another difficulty, in part related to the viscosity problem, is incomplete combustion. Gradual accumulation of the fuels on engine parts results in charred deposits, and the buildup of fuel in the crankcase eventually leads to viscosity changes in the lubricating oils.

"Right now, we're looking at the fundamental chemistry of these oils



ARS chemist Marvin Bagby demonstrates the viscosity differences in various fuels, evident by the rate in which steel balls fall through columns of the fuels. (K-2609-12)

Several oilseed crops have been tested as fuel for diesel engines. Among them are soybeans, sunflower, safflower, and rape. "Of these, soybeans have been and continue to be our major emphasis," he says. "Soybeans contain about 18 percent oil and are the one major oilseed available in surplus."

Bagby, based at the Northern to generate a more technical base from which to work," Bagby says.

Should a major energy emergency suddenly occur, he says, accelerated research and some engine maintenance modifications would allow farm tractors to operate on vegetable oils during the crisis periods of planting and harvest.

Marvin O. Bagby is in USDA-ARS Oil Chemical Research, Northern Regional Research Center, 1815 North University St., Peoria, IL 61604 (309) 685-4011. ◆

Solar Energy Research Institute

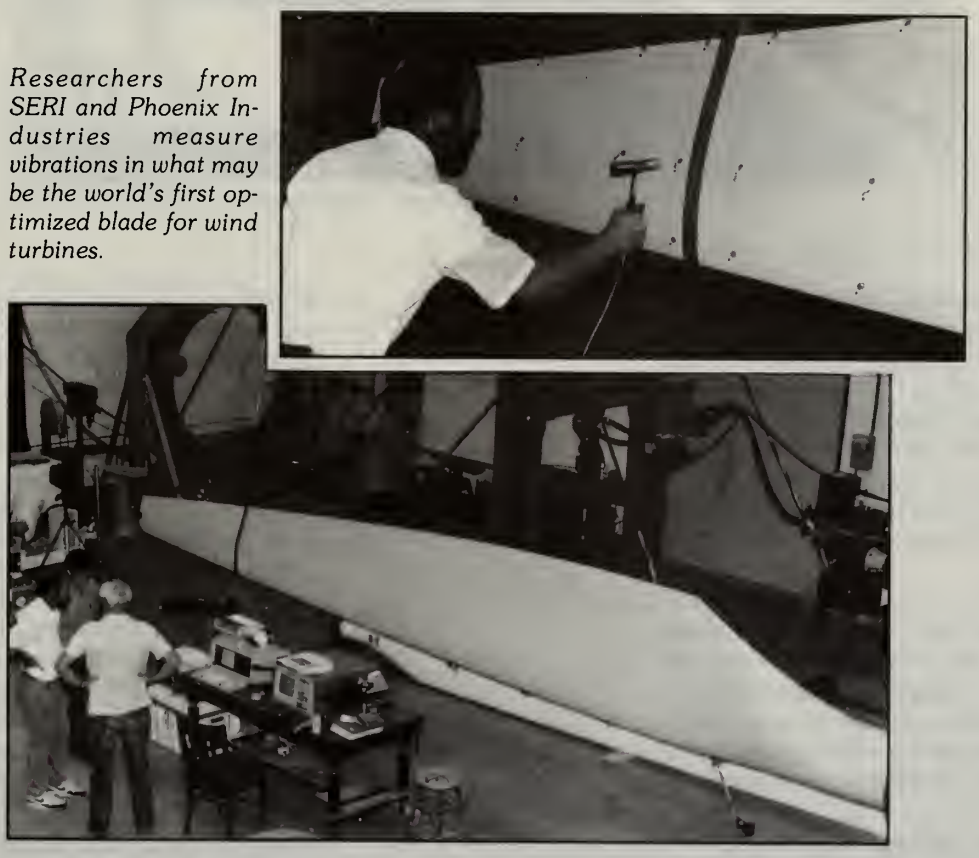
Optimized Wind Turbine Blades

SERI researchers have just completed vibrational tests of what may be the world's first optimized wind turbine blades, and the word is almost "go" for field tests in California's rugged San Gorgonio mountains.

SERI's unique 7.9-m fiberglass blades were tested using the modal survey technique, in which the blade was struck with a special impact hammer. Resulting vibrations were accurately measured and analyzed to determine fundamental modes (the frequencies at which vibrations peak).

Analysis revealed that the blades are structurally sound. It also revealed that none of the blade's vibrational modes occur in conjunction with the turbine's vibrational modes, a condition that could lead to severe blade damage.

Fatigue and load tests are next on the agenda. Once the blades pass these rigorous tests, they will be ready for installation on a Micon 65 turbine in a



Researchers from SERI and Phoenix Industries measure vibrations in what may be the world's first optimized blade for wind turbines.

windfarm northeast of Palm Springs. A nearby machine equipped with conventional blades will be part of the side-by-side comparison tests conducted for SERI by SeaWest Energy Group of San Diego, Calif.

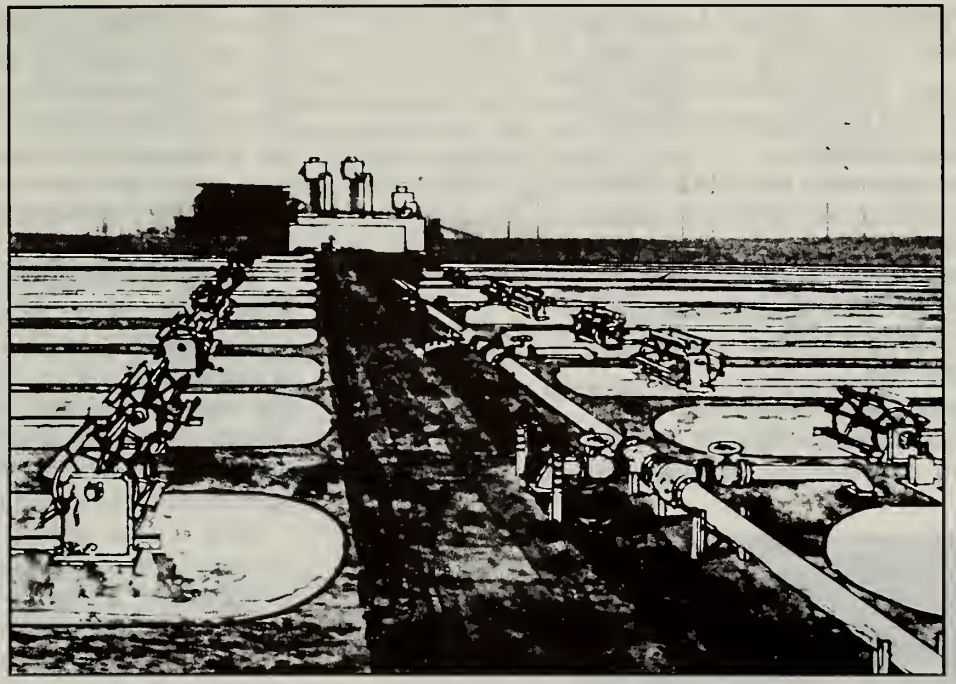
SERI's new blades were developed in cooperation with three companies. Airfoils Inc. of Hampton, Va., designed the first airfoils suitable for the special operating requirements of wind turbines. Lightweight blades based on these airfoils were designed by West-Wind Industries of Davis, Calif., and manufactured by Phoenix Industries of Crookston, Minn.

For Additional Information:

Richard Osgood
Solar Energy Research Institute
1617 Cole Boulevard
Golden, CO 80401-3393
(303) 231-7149

Refer to Volume XI, Number 2/TN

Microalgae Consume Greenhouse Gases While Producing Fuel



An artist's concept of a microalgae farm overlays a photo of a remote power plant.

Microalgae may one day trap some of the carbon dioxide responsible for the greenhouse effect and turn it into liquid fuel and other useful products. These single-cell plants, which consume 20 times more carbon dioxide per unit of land area than crop plants, are the key to such facilities.

Since 1979, SERI researchers have been developing microalgae as a biomass resource for the production of liquid fuels. Their research has resulted in methods of using microalgae to biologically trap carbon dioxide, which is produced by the burning of coal and oil and contributes to global warming (the greenhouse effect) as it accumulates in the atmosphere.

Under current plans for microalgal biomass-to-fuel technology, microalgae have the potential of using 160 billion kilograms of carbon dioxide per year for production of fuel and other products such as specialty fatty acids and natural pigments.

The use of microalgae is preferable to other carbon dioxide reduction schemes, which, some analysts predict, would greatly affect existing utility operations and increase the cost of electricity by at least 75%.

The desert Southwest, with abundant expanses of flat land, high solar radiation, few competing land uses, and availability of large saline aquifers, is an ideal initial location for microalgae farms. Other areas of the country and globe also have potential for such installations.

Contact: Dr. Lew Brown
(303) 231-1321

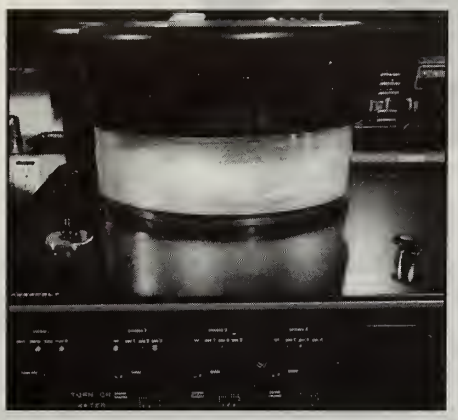
Solar Energy Research Institute

Rapid Process Makes Energy-Smart Windows

An increasing number of windows in homes, offices, and vehicles may soon have "energy smarts," thanks to a high-speed coating process recently developed at SERI.

The patented process, called plasma-enhanced chemical vapor deposition (PECVD), is 20 to 100 times faster than conventional processes used to form electrochromic coatings, including thermal evaporation and sputtering.

Speed is achieved through radio-frequency excitation of a gas mixture such as molybdenum hexacarbonyl plus oxygen. Metal oxide deposits on the selected surface all at once, a significant improvement over point and line deposition methods. And because the process occurs at room temperature, plastic and other heat-sensitive materials can now be coated as easily as glass.



Electrochromic coatings are rapidly formed on glass or plastic by plasma-enhanced chemical vapor deposition.

Energy-smart electrochromic coatings darken in response to a low-voltage electric current. Transparency is restored when the current passes in the opposite direction. Any degree of opacity can be set, allowing the coating to automatically adjust heat and light levels within a building or vehicle.

SERI is now seeking industry collaborators to develop the PECVD process for a specific consumer product. Possibilities include windows, windshields, rear-view mirrors, electronic displays, and sunglasses.

For Additional Information:

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(303) 231-1081

Refer to Volume XI, Number 2/TN

NASA Tech Brief
National Aeronautics and
Space Administration

Advanced Small Rechargeable Batteries

Lithium-based units may offer the highest performance.

A paper reviews the status of advanced, small rechargeable batteries. It covers aqueous systems including lead/lead dioxide (better known as "lead/acid"), cadmium/nickel oxide, hydrogen/nickel oxide, and zinc/nickel oxide, as well as nonaqueous systems. All based on lithium anodes, the nonaqueous systems include solid-cathode cells (lithium/molybdenum disulfide, lithium/titanium disulfide, and lithium/vanadium oxide); liquid-cathode cells (lithium/sulfur dioxide cells); and a new category, lithium/polymer cells.

The use of rechargeable batteries continues to expand as their specific energies and volumetric energy densities increase. In consumer applications particularly, greater volumetric energy densities translate into smaller sizes of equipment.

The latest interest focuses on the nonaqueous lithium systems. They offer substantially higher specific energies (100 to 125 watt-hours/kilogram) and volumetric energy densities (150 watt-hours/liter) than aqueous systems. Lithium systems are still largely experimental. Only one, the lithium/molybdenum disulfide ("Molicel") type, is being manufactured in a commercial pilot plant and is available only as samples for evaluation. The most promising development in lithium nonaqueous systems is the use of polymer electrolytes instead of liquid electrolytes. The solid polymer eliminates leakage and makes it possible to produce batteries on a continuous assembly line with a minimum of handling.

Many advanced types of aqueous batteries are readily available. The best known of these are the small sealed lead/lead oxide and nickel/cadmium. Less well known are the nickel/hydrogen versions, most of which are too large and expensive for use by consumers.

The paper reviews the criteria for the selection of a battery and describes packages for small batteries. It reports on aqueous technology, noting several important innovations, including notably the bipolar versions of the sealed lead/lead oxide battery. These versions are designed for high pulsed power and deep discharge.

This work was done by Gerald Halpert of Caltech for **NASA's Jet Propulsion Laboratory.** *"Advanced Small Rechargeable Batteries."*
NPO-17396/TN

FOR ADDITIONAL INFORMATION: *Contact: Director, Technology Transfer Division, P.O. Box 8757, BWI Airport, MD 21240; (301) 621-0100 Ext. 241*
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Engineering

0952 Laminar Digital Logic Elements

0953 High-Head Variable-Multiple-Orifice Throttling Valve

0954 Zinc-Containing Wastes Used for Electrogalvanizing

0955 Handbook of Biomass Downdraft Gasifier Engine Systems

0956 Alignment System for Docking Control—The direction and polarization of a light beam would provide attitude references.

0957 Effects of Pyrotechnically Generated Shocks—A research program of the pyrotechnic phenomenon for design purposes.

0958 Research in Microgravity on Earth—Relatively economical and accessible facilities are described.

0959 Optical Tracker for Longwall Coal Shearer—A photographic record yields information for correction of the vehicle path.

0960 Simplified Rotation in Acoustic Levitation—Rotation is controlled with simple, cheap equipment. (Licensing Opportunity)

Software

0961 AutoCAD-to-GIFTS Translator Program—Data from drafting programs are used to create finite-element mathematical models.

0962 Simulation of Failures and Repairs—Reliability and maintainability of a complicated system can be estimated.

Testing & Instrumentation

0963 Fluidic Fluid Property Meter Developed

0964 Technique Aids Ventilation Research

0965 Heated Rack for Weathering Tests—Aging of the tested material is accelerated, but under almost-natural conditions.

0966 Measuring Tension in a Tether—Tension would be measured at points along the length instead of at the ends.

Other Items of Interest

0946 Microtronic Flow Transducer—This device is much smaller and more sensitive than existing flowmeters.

0948 Optimized Wind Turbine Blades

0968 Expert Systems Developed a Never Ending Management Process for Production Engineering

0971 AutoCAD-to-NASTRAN Translator Program—This program facilitates the creation of finite-element mathematical models from geometric entities.

0981 Resistance to Delamination in Composite Materials—A fracture-mechanics approach is applied to delamination failures. (Licensing Opportunity)

0998 Continuously-Variable Vernier Scale—An easily fabricated device increases precision in reading graphical data. (Licensing Opportunity)

U.S. Army Fact Sheet

Laminar Digital Logic Elements

Laminar flow fluidic elements have many inherent advantages over turbulent flow devices. These advantages include high signal-to-noise ratio and low power consumption. One of the best known laminar flow components is the fluidic laminar proportional amplifier (LPA) which is an analog device. When an LPA is driven to saturation with a positive feedback signal, the output behaves in a digital manner. Thus, it is possible to design digital functions such as AND/OR and flip-flop using LPA's with positive feedback.

A schematic diagram of a laminar AND/OR logic element is shown in figure 1. This element consists of two LPA's, two feedback resistors and two input resistors configured as shown. This circuit can be made to function either as an AND or as an OR device through appropriate selections of the input resistors and feedback resistors together with the gain of LPA-1. The second LPA (LPA-2) decouples the output from the input of this logic element so that the switching threshold is independent of the output loading. This decoupling feature is important in digital logic systems. Figure 2 shows a typical input-output characteristic for the laminar AND/OR logic element.

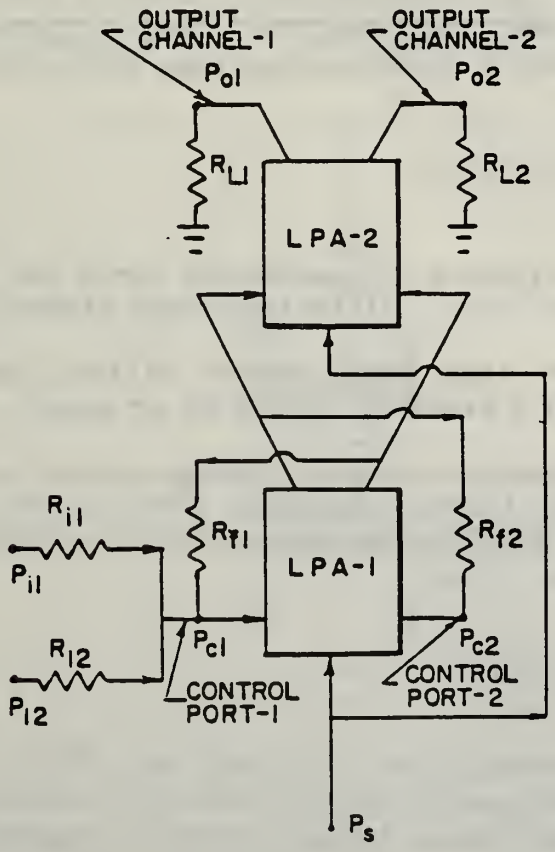


Figure 1. Schematic of AND/OR logic element.

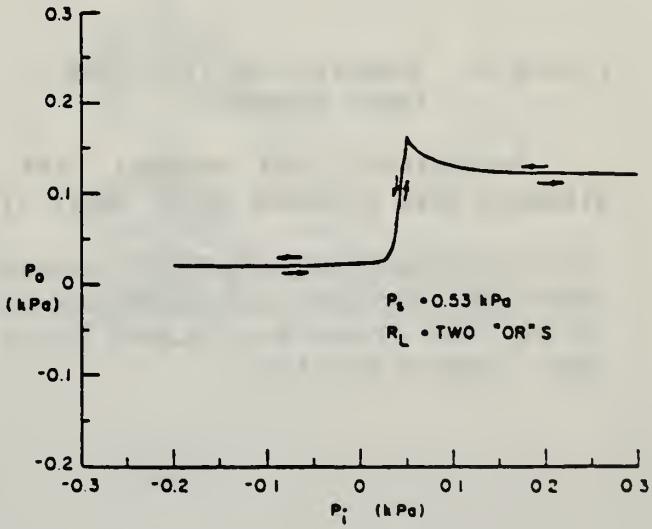


Figure 2. Input-output curve for AND/OR logic element.

Similarly, the schematic for a laminar flip-flop is shown in figure 3, and its corresponding typical input-output curve is shown in figure 4. Other digital logic functions, such as Schmitt trigger, NAND, NOT, etc., can be achieved by circuits similar to those shown.

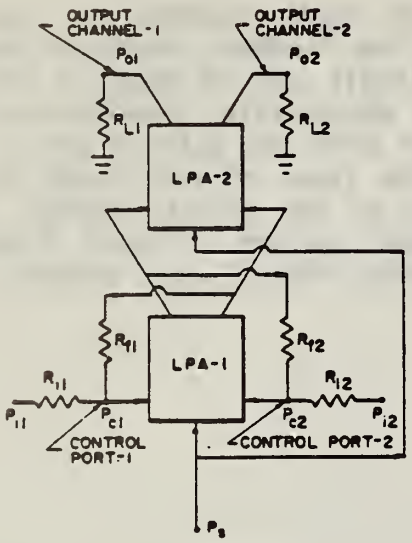


Figure 3. Schematic of flip-flop logic element.

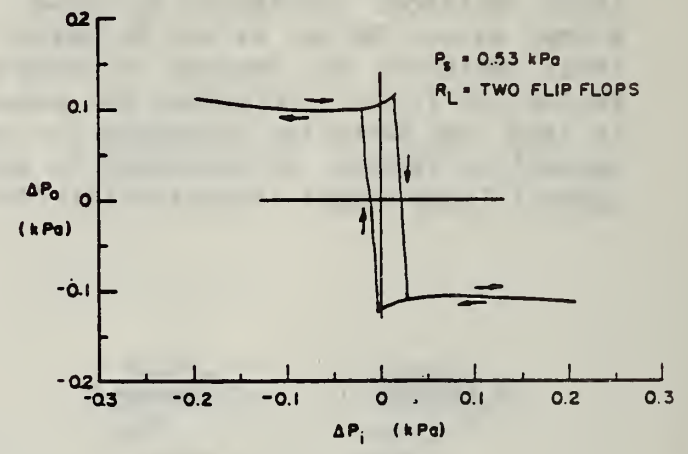


Figure 4. Input-output curve for flip-flop logic element.

Preliminary test results have shown that these laminar digital logic elements have a fanout of at least six and a bandwidth of 100 Hz or more.

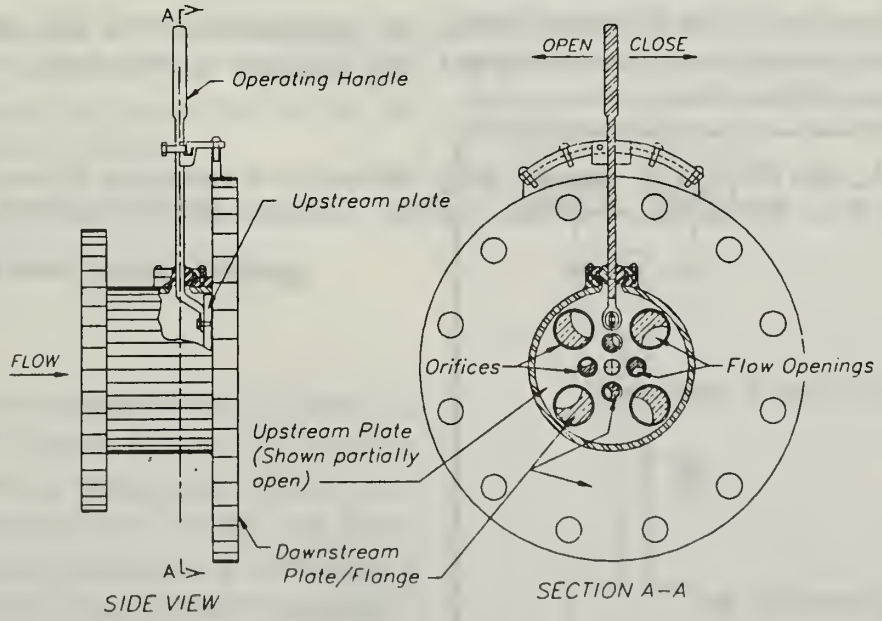
FOR ADDITIONAL INFORMATION: For further information on laminar digital logic elements and other fluidic components and systems, contact: Harry Diamond Laboratories, ATTN: DELHD-RT-CD, Fluid Control Branch, 2800 Powder Mill Road, Adelphi, Maryland 20783; (202)294-3080. Refer to FC-110.

High-Head Variable-Multiple-Orifice Throttling Valve

Large water conduits and siphons are drained periodically to perform maintenance. Severe cavitation often occurs when flow control devices such as butterfly valves, gate valves, ball valves, and plug valves are used to drain high-pressure conduits. The cavitation produces vibration and high noise levels, and often damages the control device and conduit. These conditions greatly reduce valve life, are a source of danger to personnel, and could cause damage to surrounding structures. To address these problems, the high-head variable-multiple-orifice throttling valve was developed in the Bureau of Reclamation's hydraulic laboratory.

The valve, developed by Thomas J. Isbester, is well suited for use in bypass filling lines, high-head siphon drains, and high-head pump lines. It is applicable for both free flow and submerged releases.

The valve consists of two circular steel plates separated by a low-friction-bearing surface. Each plate has small holes (orifices). The downstream plate is fixed, and the upstream plate rotates. When the valve is closed, the holes in the two plates are not aligned. As the upstream plate rotates in relation to the downstream plate, the flow opening becomes larger, until at full opening all holes in both plates are completely aligned. Several types of operating mechanisms are possible; a hand-operated handle is shown in the drawing.



At partial valve openings, a vortex is created downstream from the valve during submerged releases. This vortex results in increased energy dissipation. The vortex also helps to keep damaging cavitation toward the center of the flow, thus preventing pipe deterioration downstream of the valve.

The valve is designed for a larger diameter pipe mounted downstream of the valve. This enlargement protects the downstream pipe from cavitation damage resulting from high-intensity shear produced by the jets shooting through the orifices.

The high-head test facility in the hydraulic laboratory was used to test a 6-inch variable-multiple-orifice throttling valve. It was operated with up to 100 feet of differential pressure head at 100 percent opening and with up to 350 feet of differential pressure head at 33 percent opening. During the extensive laboratory test program, no cavitation damage was evident on the pipe wall downstream of the valve or on the valve face. Severe vibration occurred in the valve when both discharge and differential head were very high. Operational information and limits were established through the laboratory tests.

The high-head variable-multiple-orifice throttling valve should provide an economical and practical solution for a common operational problem that occurs at many Reclamation facilities. It may also apply to similar problems at municipal water supply and state facilities that require high-head flow control devices in large conduits and siphons.

Additional research is planned to compare this valve with other flow control devices with potential for eliminating problems associated with flow control under high differential head. These devices include perforated plates, perforated sleeves, and a commercial throttling valve. All of these flow control devices will be investigated and compared under similar operating conditions. The results of the investigations will allow comparison of the advantages and disadvantages of each device. The throttling valve is expected to provide better energy dissipation capability and be less expensive to manufacture than the other devices.

Proposals for cooperative work for further testing and development of this valve are welcomed. It is anticipated that manufacturers of valves and other flow control devices will be interested in commercialization of this device.

FOR ADDITIONAL INFORMATION: Danny L. King, Research and Laboratory Services Division, Bureau of Reclamation, P.O. Box 25007, D-3700C, Denver, Colorado 80225; (303)236-4517. Refer to NT-89-6/TN.

Technology News

From the Bureau of Mines, United States Department of the Interior

Zinc-Containing Wastes Used for Electrogalvanizing

Objective

Develop new technology that enables the recovery or productive use of metals and minerals in wastes such as furnace flue dusts.

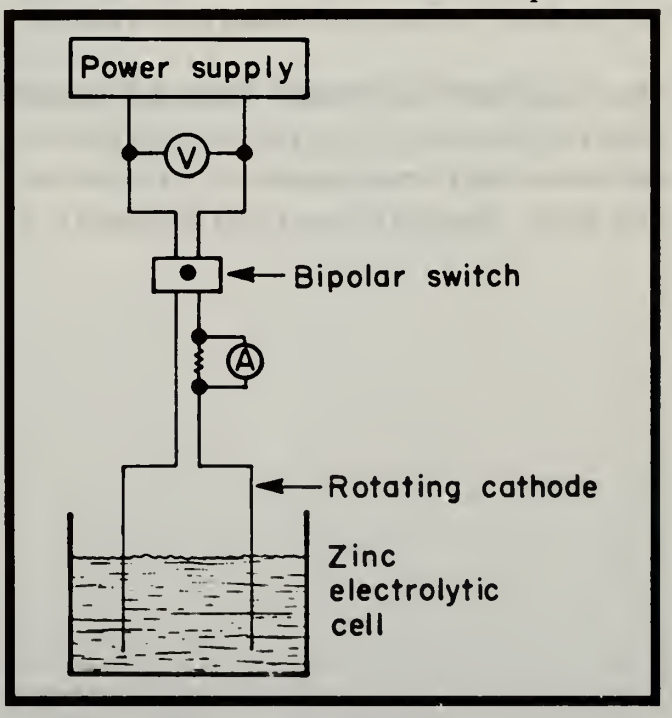
Approach

As part of the Bureau of Mines recycling research program, metallurgical furnace flue dusts were examined as a source of zinc for use in electrogalvanizing of steel.

Utilizing Zinc-Containing Wastes

A major problem facing the minerals industry is proper disposal of waste furnace dusts generated during minerals processing. Since more and more of these types of wastes are being classified as toxic or hazardous, it is becoming increasingly expensive to use the required disposal methods. New, cost-effective technologies must be devised and employed to use wastes, eliminating the need for high-cost disposal.

The Bureau of Mines, through its research effort aimed at increased recycling to conserve the Nation's resources, investigated the use of zinc-containing flue dusts as a source of zinc for use in electrogalvanizing of steel. The four waste dusts used in the study were from a secondary copper smelter, a brass smelter, a lead smelter, and a water treatment plant. The dusts were processed by being leached in H_2SO_4. Leach solutions were treated to make the electrolyte for electrogalvanizing of steel wire. Research emphasis was placed on the use of waste oxides as a source of zinc for insoluble anode processes



Laboratory apparatus used for electrocleaning and electrogalvanizing alloy steel wire.

since insoluble anodes are preferred in industrial processes. They do not require as frequent changing and the electrode gap remains more constant. During leaching, all the impurities except lead, which precipitates as insoluble $PbSO_4$, were coextracted with the zinc. Of these impurities, only copper was found to cause problems during electrogalvanizing, but was easily removed by cementation with zinc dust. Cyclic voltammetry was used in an innovative manner to evaluate the quality of the electrolytes used for electrogalvanizing. After electrogalvanizing, the wire was drawn on a laboratory draw bench to simulate industrial practice.

Test Results

Laboratory results indicated that a major problem in drawing electrogalvanized steel wire is the loss of plating material by abrasion. Bureau research showed that this loss can be greatly reduced by properly selecting drawing parameters, especially the use of low die angles and larger reductions per pass. In addition, tests showed that structural features of the plating can markedly influence drawing performance.

After successful bench-scale tests, the use of waste zinc electrolyte from the Bureau's process was successfully demonstrated at an industrial pilot plant. Results showed that although it is difficult to produce pure zinc from waste sources of zinc oxide, this less-pure material is suitable for use in electrogalvanizing.

Patent Status

The U.S. Department of the Interior has not applied for a patent on this novel process.

For More Information

A more detailed description of the results of this research is provided in Bureau Report of Investigation (RI) 9125 entitled, "Nonferrous Waste as a Source of Zinc for Electrogalvanizing." A free single copy of this RI may be obtained by writing the Bureau's Publication Distribution Section, P.O. Box 18070, Cochrans Mill Road, Pittsburgh, PA 15236. For answers to technical questions, contact:

Dr. Ernie R. Cole, Jr.
Bureau of Mines
Rolla Research Center
P.O. Box 280
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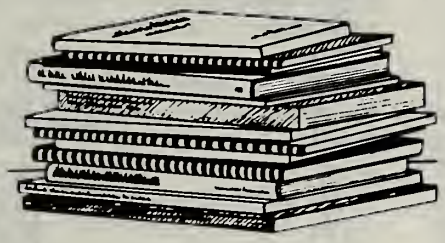
Solar Energy Research Institute

Handbook of Biomass Downdraft Gasifier Engine Systems

Recent concern about cost and availability of alternative fuels has revived interest in generating power from biomass fuels, a technology that has existed for decades but without the benefit of many written reference materials. This handbook is intended as a guide to the design, testing, operation, and manufacture of small-scale (less than 250 kW) gasifiers though much of the information is applicable to all levels of biomass gasification. Written by two experts with more than 10 years of hands-on experience, the handbook should be useful to engineers and others needing practical information about the design, construction, and operation of gasifiers. In addition to many illustrations, it contains an extensive list of references and sources of additional information.



FOR ADDITIONAL INFORMATION: A copy of the report is available from NTIS, Springfield, VA 22161; (703)487-4600.

NTIS order number: DE 88-001135/NAC

Price code: A07

NASA Tech Brief
National Aeronautics and Space Administration
Lyndon B. Johnson Space Center, Houston, Texas

Alignment System for Docking Control

The direction and polarization of a light beam would provide attitude references.

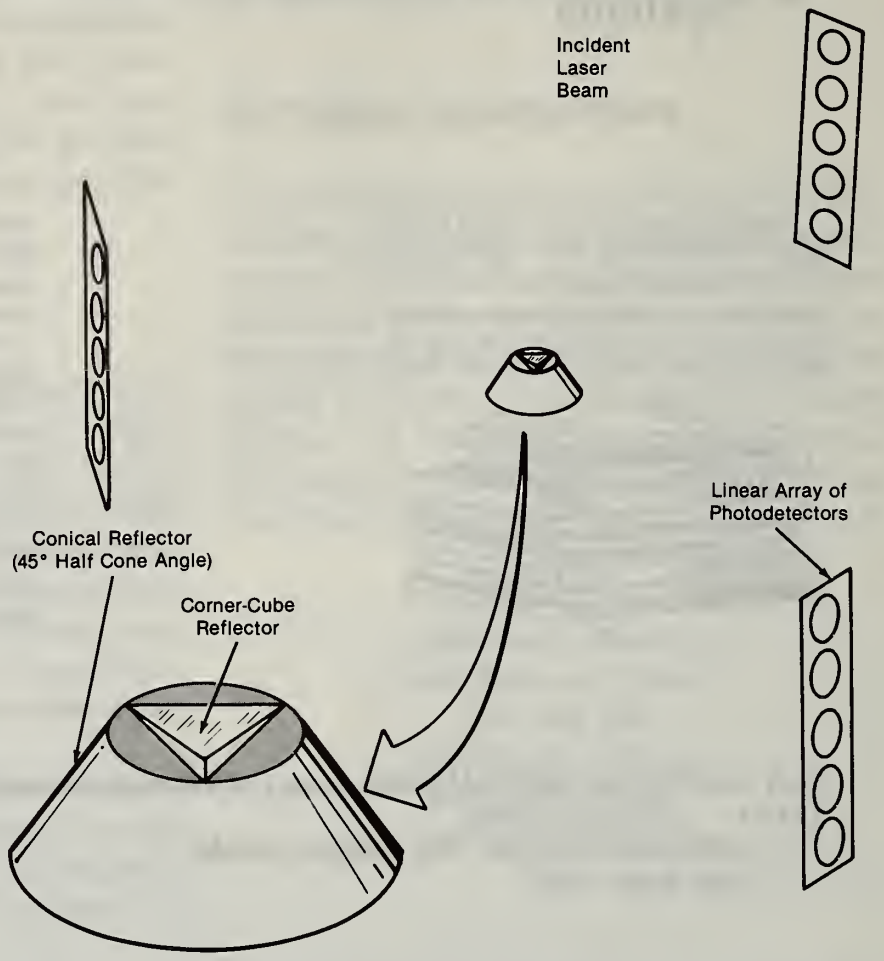
A concept for the alignment of a vehicle approaching a station is based on the generation of a coherent, polarized light or microwave beam by the station and the measurement of the beam propagation and polarization axes by the vehicle. Intended originally for use in the docking of a spacecraft with a space station, the concept may be useful for the refueling of aircraft in flight and in robotics.

In a typical one of many versions of the conceptual system, the station searches for the vehicle optically until it senses a corner-cube or other retroreflector that lies in the middle of a conical reflector (see figure). A laser in the station generates a linearly polarized light beam, which then remains aimed at the moving retroreflector as the station tracks the moving vehicle.

The conical reflector is placed on and oriented along the alignment axis of the vehicle. Three linear arrays of photodetectors, each much longer than the cone, are placed at a distance much greater than the length of the cone to catch reflected portions of the laser beam. When the laser beam and the axis of the cone are parallel (vehicle aligned), the laser beam is reflected from the cone, spreading out in a disk perpendicular to the cone. In that case, the light is intercepted by the middle photodetector or group of photodetectors in each array.

If the light beam and the axis are not parallel, the light can fall on a photodetector above or below the plane of the disk. In either case, the direction of the vehicle axis relative to that of the beam can be calculated from the positions of the three photodetectors receiving the light reflected from the cone.

The angle of roll of the vehicle about the light beam is measured by reference to the polarization axis. The cancellation of light by a polarizing filter easily establishes the polarization axis, with an ambiguity of ±180°. For roll-attitude control or for the measurement of the roll angle plus or minus the ambiguity, the incident light can be passed through two polarizing filters at 90° to each other, each covering a separate photodetector. The outputs of the photodetectors can be compared to determine the roll angle. The photodetectors can be connected in a bridge circuit to generate a null control signal to maintain a desired roll angle.



Conical and Corner-Cube Reflectors on the vehicle disperse portions of the incident light beam to sensors on the vehicle and station, respectively. The station uses the return signal for ranging and tracking. The known mathematical relationship among the direction of the beam and the positions of reflected light on the photodetector arrays can be used to calculate the orientation of the vehicle.

The distance between the station and the vehicle can be measured with the tracking-and-orienting laser beam, using one of the well-known pulse- or frequency-modulation techniques. The laser signal could also be amplitude modulated or frequency -modulated to send control signals to the vehicle, provided that the control modulation is of a type that does not interfere with the ranging function.

This work was done by Richard S. Iwasaki of Axiomatix for **Johnson Space Center**.

MSC-21156/TN

FOR ADDITIONAL INFORMATION: *Contact: Director, Technology Transfer Division, P.O. Box 8757, BWI Airport, MD 21240; (301) 621-0100 Ext. 241*
REFER TO THE NUMBER LISTED AT THE END OF THIS ARTICLE

NASA Tech Brief
National Aeronautics and Space Administration
Langley Research Center, Hampton, Virginia

Effects of Pyrotechnically Generated Shocks

A research program provides better understanding of the pyrotechnic phenomenon for design purposes.

The structural shock waves created on activation of pyrotechnic devices have the potential to damage electronic or other low-mass equipment or to activate equipment sensitive to motion. For example, a pyrotechnically induced activation of the motion-sensitive parachute release system led to the loss of two solid-rocket-booster cases of the Space Shuttle in 1983. There is a lack of information on the pyrotechnically produced loads that can be used by designers. This lack is caused by the complexity of the pulses generated and the difficulty experienced in measurement and analysis.

To evaluate the potential for damage to spacecraft by the activation of pyrotechnic mechanisms, pyrotechnic-shock tests were conducted on three configurations: (1) pin pullers on an orthogonal double Hopkinson bar arrangement, (2) pin pullers on a mockup of the Halogen Occultation Experiment (HALOE) structure, and (3) a section of separation joint on a single Hopkinson bar. Strains and accelerations were measured. The strains were converted to output stresses, forces, and moments. Acceleration shock-response spectra were obtained for both acceleration and force signals.

The devices were attached to the Hopkinson bars with adapters, which are typical of attachments used in practice. To predict the effect of the adapters, finite-element models of the adapter/bar combinations were analyzed; and results were obtained with regard to the grid size, time interval, and frequency range required to predict the response to pulses having durations of 10 to 100 μs.

One of the conclusions drawn from this study was that pyrotechnic-shock pulses can contain high-level pulses [thousands of pounds per square inch and thousands of g's acceleration (pressures of the order of tens of megapascals and accelerations of the order of 10^4 m/s^2)], with a high-frequency content up to 50 kHz. Much of the energy content is above 10 kHz. Monitoring methods must be capable of accommodating these levels. The recommended analyses of pyrotechnically generated shocks are spectral analyses, at frequencies up to 50 kHz, of both strain and acceleration histories, maintaining the association of the actual histories with the spectra.

In this study, shock spectra were obtained by a computer program that provides the peak displacement induced in damped, oscillating, spring/mass systems tuned to discrete frequencies from 0 to 50 kHz. It was found that the transmission of pyrotechnically generated shocks into a structure is influenced, as expected, by structural interfaces, materials, and distances between the source and any point on the structure.

The understanding of the pyrotechnic phenomenon has been increased considerably by this study, providing the necessary information not only for comparing various devices but for predicting the responses of structures and evaluating the potential for damage. The results of this research should be useful to designers in making comparison and evaluation tests before committing to costly spacecraft hardware.

This work was done by Laurence J. Bement of **Langley Research Center** *and Maria J. Evans and Vernon H. Neubert of Pennsylvania State University.*
LAR-13717/TN

FOR ADDITIONAL INFORMATION: *Contact: Director, Technology Transfer Division, P.O. Box 8757, BWI Airport, MD 21240; (301) 621-0100 Ext. 241*
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NASA Tech Brief
National Aeronautics and
Space Administration

Research in Microgravity on Earth

Relatively economical and accessible facilities are described.

A report surveys ground-based facilities for research in microgravity. The report notes that because of the expense and limited opportunity of conducting research in orbit around the Earth, experiments on Earth must precede and accompany research in orbit. Programs based on the ground can sharpen the focus of space research and increase the benefits derived from it. In some cases, terrestrial research may eliminate the need for trials in orbit.

The ground-based facilities fall into three categories:

1. Those that provide a true microgravity environment for a short time, such as rockets, airplanes, drop towers, and drop tubes;
2. Those that emulate one or more aspects of the microgravity environment, such as electromagnetic or acoustic levitators; and
3. Those that aid in understanding behavior of systems in microgravity, such as model furnaces and computational facilities.

The report concentrates on material-processing facilities of NASA at Lewis Research Center, Marshall Space Flight Center, and the Jet Propulsion Laboratory. It describes the facilities briefly and provides names and telephone numbers of people who can give further information and arrange for qualified researchers to use the facilities.

This work was done by Bruce N. Rosenthal and Thomas K. Glasgow of **Lewis Research Center**, *Daniel D. Elleman of Caltech for NASA's Jet Propulsion Laboratory, and Richard E. Black of Marshall Space Flight Center. Further information may be found in NASA TM-88964 [N87-16917], Price Code: A02 "Research Opportunities in Microgravity Science and Applications During Shuttle Hiatus."*

Copies may be purchased from the National Technical Information Service, Springfield, Virginia 22161, Telephone No. (703) 487-4650. Rush orders may be placed for an extra fee by calling (800) 336-4700.
LEW-14660/TN

FOR ADDITIONAL INFORMATION: *Contact: Director, Technology Transfer Division, P.O. Box 8757, BWI Airport, MD 21240; (301) 621-0100 Ext. 241*
REFER TO THE NUMBER LISTED AT THE END OF THIS ARTICLE

NASA Tech Brief
National Aeronautics and Space Administration
Marshall Space Flight Center, Alabama

Optical Tracker for Longwall Coal Shearer

A photographic record yields information for correction of the vehicle path.

A tracking system records the lateral movements of a longwall coal-shearing vehicle. The system detects the lateral and vertical deviations of the path of the vehicle as it moves along a coal face, shearing coal as it goes. The track on which the vehicle rides can then be adjusted to correct for the deviations so that error does not accumulate in subsequent passes.

A stationary tracking assembly at one end of the coal face transmits a beam of light to a retroreflector on the advancing or receding vehicle. The light reflected back to the source is recorded continuously on

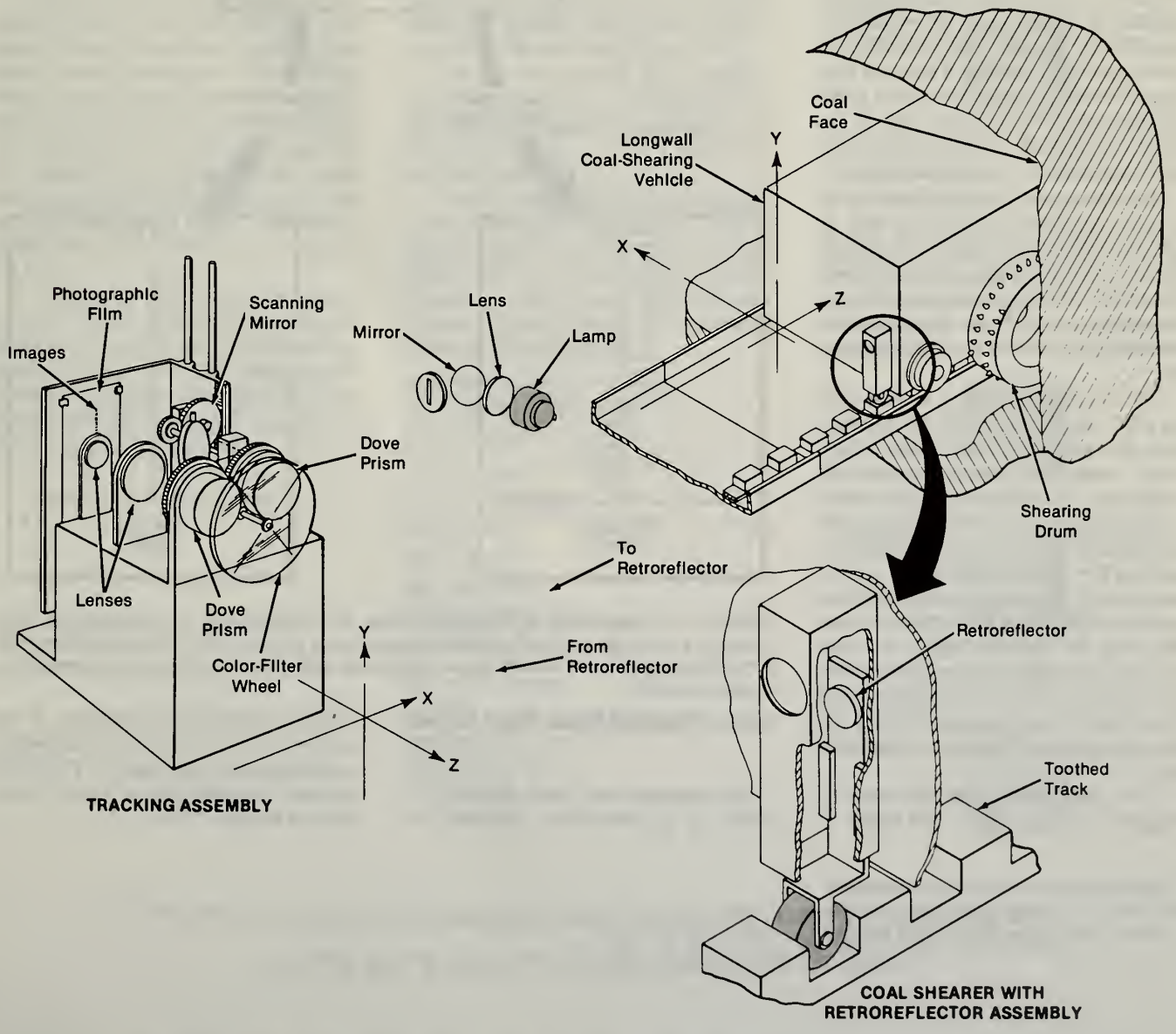

Figure 1. A **Longwall Shearer Rides on Rails** in a mine tunnel, advancing on a toothed track in one of the rails. As the vehicle moves, a retroreflective mirror rides up and down on the teeth, providing a series of pulsed reflections to a film recorder. The recorded positions of the pulses, which have horizontal and vertical orientations, indicate the vertical and horizontal deviations, respectively, of the vehicle.

film. An overlay placed on the film provides coordinates for determining the deviation of the reflected light beam and, therefore, of the vehicle.

The light source is a mine safety lamp. A lens and aperture in the tracking assembly shape the beam into one with a long, narrow rectangular cross section, and a rotating prism in the housing alternates the orientation of the long rectangular axis between horizontal and vertical. A pivoted mirror scans the beam across the path of the vehicle so that it seeks out the retroreflector.

On the vehicle, the retroreflector rises and falls as it rides on the teeth of the vehicle drive track (see Figure 1). It reflects the beam from the source only in its topmost position and thus provides a series of light pulses to the recording film, each pulse corresponding to a particular tooth in the track. The longitudinal position of the vehicle is thus always known for each pulse.

Since the source housing transmits alternating horizontal and vertical bars of light, the retroreflector returns alternating horizontally- and vertically-oriented pulsed bars of light. The horizontal pulses indicate the vertical position of the vehicle, and the vertical pulses indicate the horizontal position.

In the tracking assembly, a second rotating prism, synchronized with the first, converts the vertical reflected pulses to horizontal, leaving the horizontal reflections unchanged. The reflections are focused into small images of horizontal bars on color photographic film. The film is moved upward as the vehicle advances, so that the sequence of images is a plot of the vertical and lateral deviations as a function of position along the path (see Figure 2). A synchronized rotating color filter gives distinctive colors to the vertical-deviation and horizontal-deviation traces so that they can be distinguished on the color photographic film.

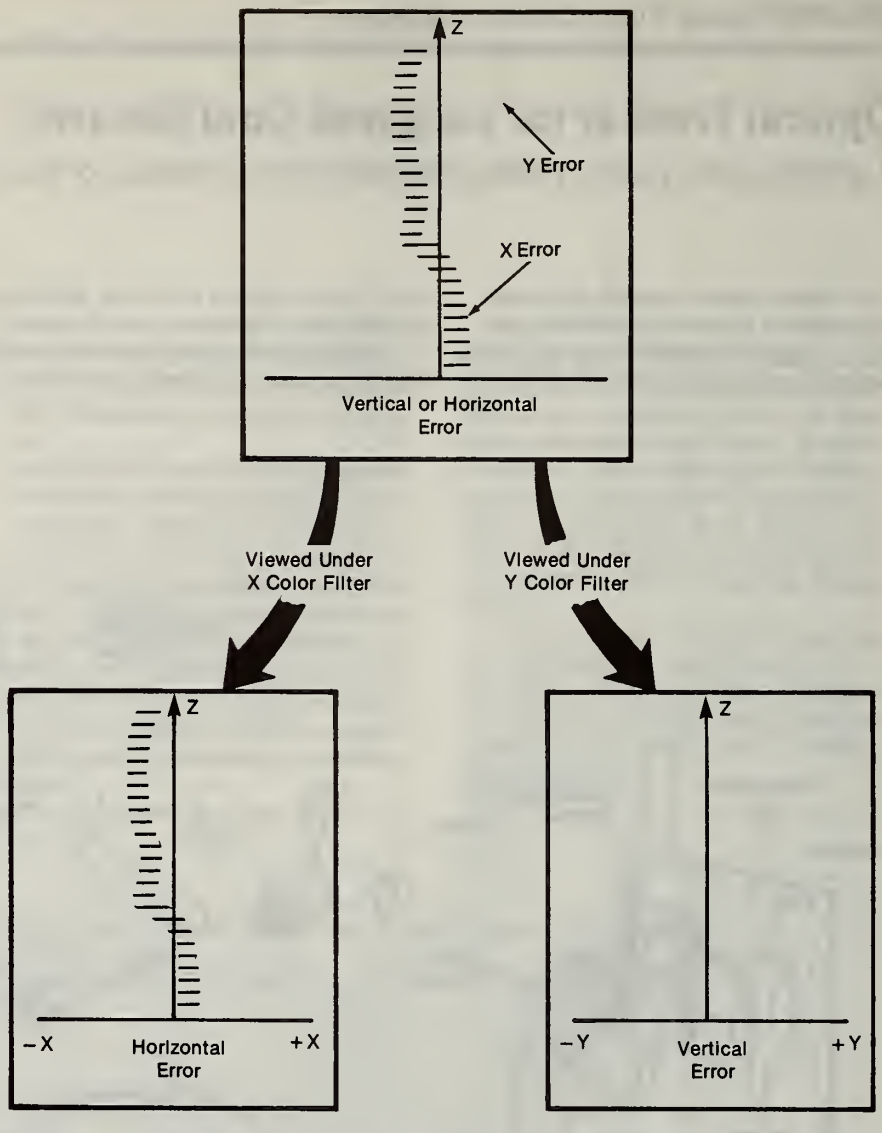

Figure 2. Two **Sequences of Horizontal Lines** on photographic film indicate the path traveled by the longwall shearer. Each sequence has a distinct color to facilitate interpretation of the images: when the film is examined under a suitable color filter, only one sequence is seen at a time.

This work was done by Peter D. Poulsen, Richard J. Stein, and Robert E. Pease of **Marshall Space Flight Center**.

This invention has been patented by NASA (U. S. Patent No. 4,466,667). Inquiries concerning nonexclusive or exclusive license for its commercial development should be addressed to the Patent Counsel, Marshall Space Flight Center Refer to MFS-25717/TN

FOR ADDITIONAL INFORMATION: *Contact: Director, Technology Transfer Division, P.O. Box 8757, BWI Airport, MD 21240; (301) 621-0100 Ext. 241*
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NASA Tech Brief
National Aeronautics and Space Administration
NASA's Jet Propulsion Laboratory, Pasadena, California

Licensing Opportunity

Simplified Rotation in Acoustic Levitation

Rotation is controlled with simple, cheap equipment.

A simple new technique based on an old discovery can be used to control the orientation of an object levitated acoustically in an axisymmetric (circular cylindrical or spherical) chamber. This method does not require expensive equipment like additional acoustic drivers of precisely adjustable amplitude, phase, and frequency.

Lord Rayleigh demonstrated that a nonspherical object becomes oriented in a sound field with the axis along which it appears to have the largest cross-sectional area pointing along the direction of propagation of the sound. This principle can be exploited to control the orientation of an object levitated in an axisymmetric sound field by placing in the chamber a sound-reflecting object that is shaped, positioned, and/or oriented to break the symmetry of the field.

The reflecting object acts as a second source of sound. If the reflecting object is large enough, close enough to the levitated object, or focuses the reflected sound sufficiently, the Rayleigh torque exerted on the levitated object by the reflected sound controls the orientation of the object.

The figure shows some of the many possible configurations of orienting reflectors. Different reflectors can be moved in turn into proximity with the levitated object to obtain different orientations. Alternatively, a reflector can be rotated about the axis of the levitator to orient the levitated object along any desired azimuth. The reflector can be turned continuously by a motor to make the levitated object rotate continuously with the reflector about the axis.

This work was done by M. B. Barmatz, M. S. Gaspar, and E. H. Trinh of Caltech for **NASA's Jet Propulsion Laboratory**. *For further information, Circle 121 on the TSP Request Card.*

This invention is owned by NASA, and a patent application has been filed. Inquiries concerning nonexclusive or exclusive license for its commercial development should be addressed to the Patent Counsel, NASA Resident Office-JPL. Refer to NPO-17086/TN.

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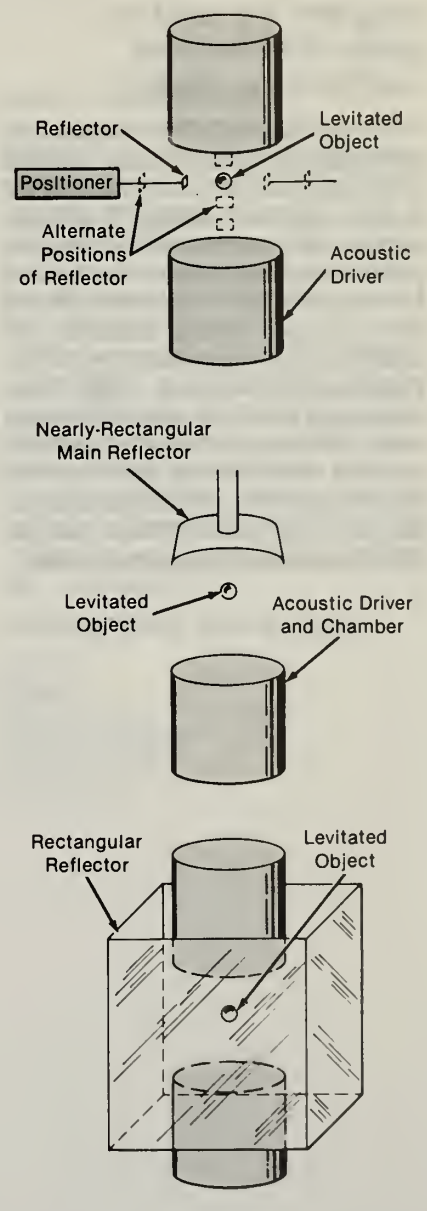

Reflectors That Break the Axisymmetry of the acoustic levitator produce Rayleigh torques that orient the levitated object.

FOR ADDITIONAL INFORMATION: *Contact. Director, Technology Transfer Division, P.O. Box 8757, BWI Airport, MD 21240; (301) 621-0100 Ext. 241*
REFER TO THE NUMBER LISTED AT THE END OF THIS ARTICLE

NASA Tech Brief
National Aeronautics and Space Administration

AutoCAD-to-GIFTS Translator Program

Data from drafting programs are used to create finite-element mathematical models.

The AutoCAD-to-GIFTS translator program, ACTOG, was developed to facilitate quick generation of small finite-element models using the CASA/GIFTS finite-element modeling program. ACTOG reads the geometric data of a drawing from the Data Exchange File (DXF) used in AutoCAD and other PC-based drafting programs. The geometric entities recognized by ACTOG include points, lines, arcs, solids, three-dimensional lines, and three-dimensional faces. From this information, ACTOG creates a GIFTS SRC file, which can then be read into the GIFTS preprocessor BULKM or can be modified and read into EDITM to create a finite-element model.

The GIFTS commands created include KPOINT's, SLINE's, CARC's, GRID3's, and GRID4's. The SRC file can be used as is (using the default parameters) or edited for any number of uses. It is assumed that the user has at least a working knowledge of AutoCAD and GIFTS.

ACTOG was written in Microsoft QuickBasic (Version 2.0). The program was developed for the IBM PC and has been implemented on an IBM PC-compatible computer under DOS 3.21. ACTOG was developed in 1988.

This program was written by Andrew Jones of **Goddard Space Flight Center.**
GSC-13211/TN

FOR ADDITIONAL INFORMATION

CONTACT:
COSMIC®
112 Barrow Hall
University of Georgia
Athens, GA 30620
(404) 542-3265

Simulation of Failures and Repairs

Reliability and maintainability of a complicated system can be estimated.

The Automated Reliability/Availability/Maintainability (ARAM) computer program is one of the software tools designed to assess candidate architectures of the data-management system of the Space Station. It evaluates the reliability, availability, and maintainability characteristics of the conceptual system. ARAM uses the data representing the redundancy characteristics of the system (redundancy diagram), the maintainability characteristics of the system, and the reliability parameters of components of the equipment.

"Reliability" as used here means the probability that a function is performed without interruptions within a given time interval. For any unit, the time between failures is assumed to have an exponential probability distribution defined by its mean time between failures. "Maintainability" as used here means the probability that a function is restored within a given time interval. Parameters include repair-service priority, mean time to repair, and availability of spare parts. Maintainability includes such global parameters as the period for replenishment of spare parts and the number of repair technicians.

The ARAM design is based upon the simulation of failures and the possible subsequent repairs of each unit of equipment included in the system. It analyzes the effects of failures and repairs on the system and maintains statistics of the behavior of the system from which the results of the simulation are obtained. During a typical ARAM simulation, when the clock advances to a failure event, the program assesses whether any group fails because of failure of a unit. It then propagates the failure event to all affected groups. Next, ARAM generates a unit-repair event for the repairable unit. Other choices include on-line or off-line backup units. The simulation can be repeated a specified number of times for each one of the seeds specified for the random-number generator, or can be timed. At the end of a simulation, the program computes the average statistics.

ARAM is delivered as a package of files that include the program for the generation of the model and for the simulation, and the template for the data base of the model. A data-base-conversion program enables the users of the previous Version 1.0 to convert their model Version-1.0 data bases to the Version-2.0 format.

ARAM was written for an IBM PC XT/AT or compatible computer. It requires 512K of random-access memory, a hard disk, a printer with 132 columns, and DOS 2.1 or higher. ARAM was developed in 1987.

This program was written by Antonio Vallone and Jack P. Craig of Computer Sciences Corp. for **Langley Research Center**. *LAR-13997/TN*

FOR ADDITIONAL INFORMATION

CONTACT:
COSMIC®
112 Barrow Hall
University of Georgia
Athens, GA 30602
(404) 542-3265

U.S. Army Fact Sheet

Fluidic Fluid Property Meter Developed

A Fluidic Fluid Property Meter (FPM) has been developed by the U.S. Army's Harry Diamond Laboratories in Adelphi, Maryland. The FPM is a device that measures fluid density, viscosity, mass flow rate, and volumetric flow rate of virtually any homogeneous fluid (Newtonian). The device has no moving parts and requires no power input other than the fluid stream which is being measured. As a result, this device has inherent advantages compared with conventional methods of measurement, particularly in the areas of reliability and ability to operate in harsh environments. Because the FPM has no moving parts it is extremely reliable. The fluidic laminates which comprises the device can be manufactured from a wide range of materials such that it can effectively withstand the stress of a high temperature or caustic environment.

The development of this device to its full potential is considered to be outside the mission area of HDL. Commercialization of the device is the intention of HDL through either 1) a program of collaborative research and/or 2) patent licensing (which could be exclusive).

FOR ADDITIONAL INFORMATION: Contact George Gillespie, Harry Diamond Laboratories SLCHD-TT, 2800 Powder Mill Rd., Adelphi, MD. 20783-1197; Phone: 301-394-4120.

Solar Energy Research Institute

Technique Aids Ventilation Research

SERI researchers are using an image analysis system similar to those in remote-sensing applications to study the performance of ventilation systems. The study seeks to determine relationships between building ventilation rates and air quality in the occupied zone (a room's volume to the height of about 6 feet).

The special image analysis system allows researchers to study the ability of a ventilation system to deliver air to the occupied zone and to remove pollutants before they mix with air in that space. The technique is being applied to advanced and conventional ventilation systems.

SERI's system is a significant improvement over previously used point measurement systems, which sample air at only a few points in the occupied zone. The image analysis system expands this capability by producing a digitized image of tinted fluid in a simulation of air movement through the occupied zone. This digitized image provides more than 367,000 points at which optical density can be measured to determine pollutant concentration.

The system's greater spatial resolution allows highly accurate local measurements of air movement and pollutant distribution so that researchers can make realistic assessments of human exposure to room contaminants. In addition, designers can use the system to minimize flow short-circuiting and poor air distribution effects.

For Additional Information:

Ren Anderson
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1617 Cole Boulevard
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(303) 231-1756

Refer to Volume XI, Number 2/TN

NASA Tech Brief
National Aeronautics and Space Administration
NASA's Jet Propulsion Laboratory, Pasadena, California

Heated Rack for Weathering Tests

Aging of the tested material is accelerated, but under almost-natural conditions.

The outdoor photothermal aging reactor (OPTAR) is a simple device that exposes polymer specimens to both heat and natural sunlight. The device is intended to provide accelerated aging data for the service life of polymers used in an outdoor environment. In principle, the OPTAR accelerates (but does not initiate) the degradation of polymers that results from sunlight and other weathering effects (eg., rain, wind, ozone).

The OPTAR offers an important advantages over accelerated-aging chambers equipped with artificial light sources: firstly, it uses natural sunlight, which ic real and more consistent than artificial sources and, secondly, heat is the only accelerated stress and is easily regulated. The method also provides exposure to natural environmental conditions, including dark periods (during which some other chemical reactions occur). Data obtained from these tests can be used with confidence to predict lifetimes under natural aging at ambient temperatures.

The OPTAR is built around an aluminum plate 1 m square and 1.27 cm thick. Silicone heaters that have a power density of 5 W/(in.)^2 [0.8 W/(cm)^2] are bonded to the underside of the plate by silicone adhesive. A sheet of stainless steel is bonded similarly to the top side. A J-type thermocouple placed in a well drilled 20 cm deep in the side of the plate measures the temperature and serves as part of a thermostatic control for the heaters. The assembly is mounted in a heavy, framed wooden enclosure so that only the stainless-steel face is exposed. The specimens are clamped flush on this surface, aged for specific intervals, then removed for determinations of their properties as a function of time and temperature.

Many chemical reactions are based on simple first-order kinetics, in which the logarithm of a property of interest is found to change linearly with time. Polymers frequently depart from this type of behavior and exhibit an induction period, after which a given property changes suddenly (for example, elongation at break). Predictions of natural aging from accelerated data may be determined by plotting the logarithm of the induction period against the reciprocal of the absolute temperature, in accordance with the Arrhenius relationship. It has been found that these plots are linear and may be extrapolated to ambient temperatures to obtain the polymer lifetime under actual service conditions.

This work was done by Edward F. Cuddihy and Paul B. Willis of Caltech for **NASA's Jet Propulsion Laboratory**.

This invention is owned by NASA, and a patent application has been filed. Inquiries concerning nonexclusive or exclusive license for its commercial development should be addressed to the Patent Counsel, NASA's Resident Office-JPL
Refer to NPO-17524/TN

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NASA Tech Brief
National Aeronautics and Space Administration
Marshall Space Flight Center, Alabama

Measuring Tension in a Tether

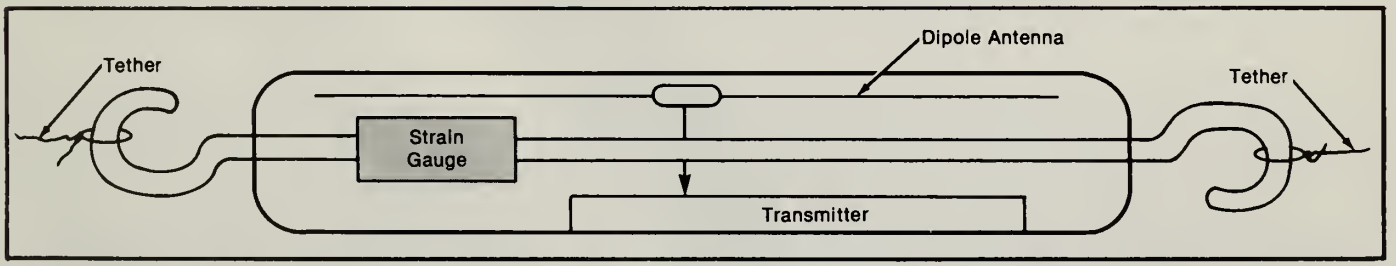
Tension would be measured at points along the length instead of at the ends.

A proposed instrument would measure the tension in a tether and transmit data on the tension so that the tension could be monitored or adjusted as necessary. Many such instruments could be positioned along the length of the tether (see figure), unlike currently available devices, which can measure tension only at the ends.

Measurements of the distribution of tension along a tether will enable more-responsive and more-adaptive control. Tension could be adjusted to change the shape of traveling waves on the line, for example. In addition, peak tension could be sensed wherever it occurs. Higher end tension might then be applied, because tension would no longer have to be limited to an arbitrary value to avoid exceeding the maximum allowable tension at an unknown point on the line.

The device would include a strain gauge to sense the tension. The output of the strain gauge could control the modulation of a battery- or solar-powered radio transmitter. In another version, the transmitter could be a "passive nonlinear reflector," which would receive a radio signal on one frequency and return a signal on another frequency with modulation that signifies the tension. In yet another version, data on the tension could be carried on a beam of light. A laser-diode transmitter could be powered by a battery, a radio beam, a beam of light, or solar energy.

This work was done by E. M. Hinman of **Marshall Space Flight Center**. *No further documentation is available.*
MFS-28321/TN



Many **Instrument Capsules** like this one would be placed along a tether to measure the local tension. Each capsule would contain a strain gauge and transmitting electronics.

FOR ADDITIONAL INFORMATION: *Contact: Director, Technology Transfer Division, P.O. Box 8757, BWI Airport, MD 21240; (301) 621-0100 Ext. 241*
REFER TO THE NUMBER LISTED AT THE END OF THIS ARTICLE

Environmental Science & Technology

0967 New Fluorescence-Based Chemical Indicator for Detecting Chloroform and Tricloroethylene

Other Items of Interest

0954 Zinc-Containing Wastes Used for Electrogalvanizing

0983 Development of Statistical Distributions or Ranges of Standard Factors Used in Exposure Assessments

Department of Energy

Technology Application

Lawrence Livermore National Laboratory

New Fluorescence-based Chemical Indicator for Detecting Chloroform and Tricloroethylene

A new fluorescence-based chemical indicator for detecting chloroform and trichloroethylene has been developed. The researchers have isolated and identified the fluorescent products resulting from this assay using modern spectroscopic techniques. A report describes the details of this reaction, its putative reaction sequences with chloroform and trichloroethylene, and present an analysis of the spectral data obtained from the reaction products.

Preliminary measurements have been made using a fiber optic chemical sensor (optrode) for monitoring groundwater contamination that exploits this new fluorescence-based indicator for chloroform and trichloroethylene. The details of the sensor configuration and the chemical reagents employed in the transduction chemistry are reported. The researchers developed for this optrode a technique that permits the selective detection of chloroform in the presence of trichloroethylene and discuss approaches to selectively measure trichloroethylene in the presence of chloroform. The results of preliminary measurements of trichloroethylene with optrodes that contain our new chemical indicator are outlined in the report.

The researchers also report on the syntheses of several compounds that we will evaluate to improve the luminescence properties of the fluorescence-based test for chloroform and trichloroethylene.

The fiber optic organochloride sensor incorporates the new fluorescence detection chemistry and has initially been configured with two optical fibers, one to provide exciting light to the transducer and the other to transmit fluorescent light back to the photodetector. By adjusting the polarity of the solvents used in the optrode chemistry, the solubility of the volatile organohalides can be affected so that chloroform can be selectively detected in the presence of TCE. Initial data collected with the present configuration of the optrode permits head-space detection of TCE and chloroform in the range of 1 ppm to 300 ppm. Substantial lowering of the detection limit is expected with improvements in the optrode design and optics configuration.

FOR ADDITIONAL INFORMATION: A copy of the report is available from NTIS, Springfield VA 22161; (703)487-4600.

NTIS order number: DE88-016646

Price code: A03

To discuss this effort further, contact Michael Angel, Environmental Science Division, Lawrence Livermore National Laboratory, P.O. Box 5507, Livermore, CA 94550.

Manufacturing, Machinery & Tools

0968 Expert Systems Developed a Never Ending Management Process for Production Engineering

0969 Three-Dimensional Robotic Vision System—Stereoscopy and motion would provide clues to the outlines of objects.

0970 Thermal Brushes for Memory-Metal Actuators—Thermal brushes would remove or add heat for rapid actuation.

Software

0971 AutoCAD-to-NASTRAN Translator Program—This program facilitates the creation of finite-element mathematical models from geometric entities.

Other Items of Interest

0954 Zinc-Containing Wastes Used for Electrogalvanizing

0961 AutoCAD-to-GIFTS Translator Program—Data from drafting programs are used to create finite-element mathematical models.

0976 Joining Ceramics

0977 Deposition of Pinhole-Free $CoSI_2$ Film—A stoichiometric combination of cobalt and silicon is overlaid with silicon. (Licensing Opportunity)

0978 Glass Coats for Hot Isostatic Pressing—Surface voids would be sealed from pressurizing gas.

U.S. Army Fact Sheet

Expert Systems Developed A Never Ending Management Process for Production Engineering

For the past three years, engineers at the U.S. Army Missile Command (MICOM) have been designing expert and knowledge based computer programs to augment production engineering support. These efforts have been part of an overall project called the Computer-Aided Production Engineering (CAPE) Laboratory. Areas of concentration have been computer-aided design, expert systems and information management. The programs have been developed in-house with some support from contractors and a local university. Three separate systems have been developed thus far:

- Producibility/Value Engineering Expert System (PVEX),
- Production Readiness Review Expert System (PRES), and
- Guidance/Hypermedia (GUIDANCE).

PRODUCIBILITY/VE EXPERT SYSTEM

In essence, PVEX is a linkage of a computer-aided design system, a hypermedia-based knowledge management system and resident databases. The combination makes up an "intelligent" software tool. It is particularly useful for analyzing initial designs and performing both value and reverse engineering. Although it is still limited to mechanical structural type parts, it is planned to include electrical, optical and chemical functions.

The system is designed to guide engineers through a producibility or value engineering (VE) analysis. It assists engineers in selecting alternative materials and production processes.

A software shell is used to construct frames and links between frames which contain the knowledge associated with performing a producibility analysis. A frame is a screen sized worksheet which, like a sheet of paper, may contain any arrangements of text and images. Initial development efforts included PVEX accessing on-line databases to obtain the most up-to-date materials and production process information.

The materials database contains both physical data and knowledge based data such as availability, relative cost and common uses for 246 metals. The manufacturing process database contains economic and gross attribute data and knowledge such as the advantages and disadvantages for 129 processes.

The output from the producibility/VE analysis is a list of feasible materials and manufacturing processes which can be used to produce a part meeting the required function. The user has the option of generating a printout of information from any chosen database.

Currently, the expert system is being validated through testing of the knowledge bases and heuristic information. This is carried out by comparing results to that obtained using past producibility analysis techniques.

A logical extension of the PVEX system would be its incorporation into a computer integrated manufacturing system (CIM).

PRR EXPERT SYSTEM (PRES)

PRES is a compiled prolog language program that runs on an IBM compatible personal computer. It was written to assist team members in assigning risks to functional areas based on information gathered during a Production Readiness Review (PRR). The program is constructed from a series of lessons learned while conducting

PRRs over the past six years. These lessons, in combination with the Willoughby Templates (DoD 4245.7-M), form a set of evaluation criteria which are applicable to all system development efforts. These risks are assigned on the basis of the answers to questions about product design, producibility engineering, materials, purchased parts, industrial resources, quality assurance, contract administration/program management and logistics.

The answers are weighed and combined and an average is calculated to determine the overall risk assessment. The sections can be addressed as they are arranged in the program or out of sequence. If each of the seven sections cannot be completed in one answering session, the values can be stored. The remaining questions can be answered at at later time.

In addition to using it as a risk assessment tool, the system can be used by PRR team leaders to prepare for reviews and to familiarize the team members with their assigned areas of responsibility. The PRES system provides team members with a valuable preparation aid and a system of checks and balances for the team direction, enhancing standardization in the risk assessment and rating process.

GUIDANCE/HYPERMEDIA

GUIDANCE is a computerized knowledge base package being developed to aid in determining the applicable version of production engineering regulations through on-line referencing. The knowledge base will be composed of policies, directives and instructions on:

- Production Management,
- Producibility Engineering and Planning (PEP), and
- Production Readiness Reviews (PRRs).

All of these may be accessed through user friendly, menu-driven screens. This software package will provide a description of the purpose of each regulation and indicate reference regulations associated with the corresponding topics of interest.

The package operates on MICOM's regular workstations. Regulations will be optically scanned to create a library of images which will then be linked using a hypermedia tool. The linked images will form an electronic document which the user can cross reference by moving through the structure of frames. The software is designed to enhance capabilities by demonstrating hypermedia as well as provide excellent on-line explanation of reference documents.

VERY ECONOMICAL DEVELOPMENT

The three systems have been developed at a relatively low cost. Furthermore, economic analyses have shown that these costs will be repaid many times during the next few years. In addition to the systems developed, the CAPE laboratory has stimulated the organization and documentation of knowledge concerning producibility and VE.

FOR ADDITIONAL INFORMATION: More information about any of the three expert systems may be obtained by contacting Mr. Harold R. Brewer, MICOM, ATTN: AMSMI-RD-SE-PE; (205)895-4251.

NASA Tech Brief
National Aeronautics and Space Administration
Marshall Space Flight Center, Alabama

Three-Dimensional Robotic Vision System

Stereoscopy and motion would provide clues to the outlines of objects.

A proposed robotic vision system would analyze views from two television cameras to detect rigid three-dimensional objects and reconstruct them numerically in terms of the coordinates of corner points. The stereoscopy and the effects of motion on the two images would complement each other in providing the image-analyzing subsystem with clues to the natures and locations of principal features.

The brightnesses of picture elements would be turned into information about the object in view by three digital processes (see Figure 1): a low-level process to extract the corner points, a middle-level process to establish the correspondences between points in the stereoscopic (spatial) and motional (temporal) modalities, and a high-level process to compute the three-dimensional coordinates of the corner points by integration of the spatial and temporal correspondences.

Corner points would be detected by the Zuniga-Haralick corner-detecting algorithm, in which a step-edge operator based on zero crossings of second directional derivatives of brightness provides a measure of the "cornerness" of a point. The spatial correspondence of the corner points from two stereoscopic images would be found by the epipolar-line technique (see Figure 2), in which a point in the left (or right) image is tentatively said to correspond to a point in the right (or left) image if it lies close to the imaginary line (the epipolar line) in the left (or right) image that represents the line of sight from the right (or left) camera to the point in the right (or left) image. The ambiguities would be resolved and tentative identifications affirmed or denied in the higher level processes.

The temporal correspondence between points in successive images would be found by a cooperative-relaxation matching algorithm, which selects matching according to the consistencies of points and distances between points at successive image times. The temporal correspondence from two successive pairs of images would be used to resolve the ambiguities in the spatial correspondence by a two-step integration of the spatial and temporal correspondences to produce a cooperative

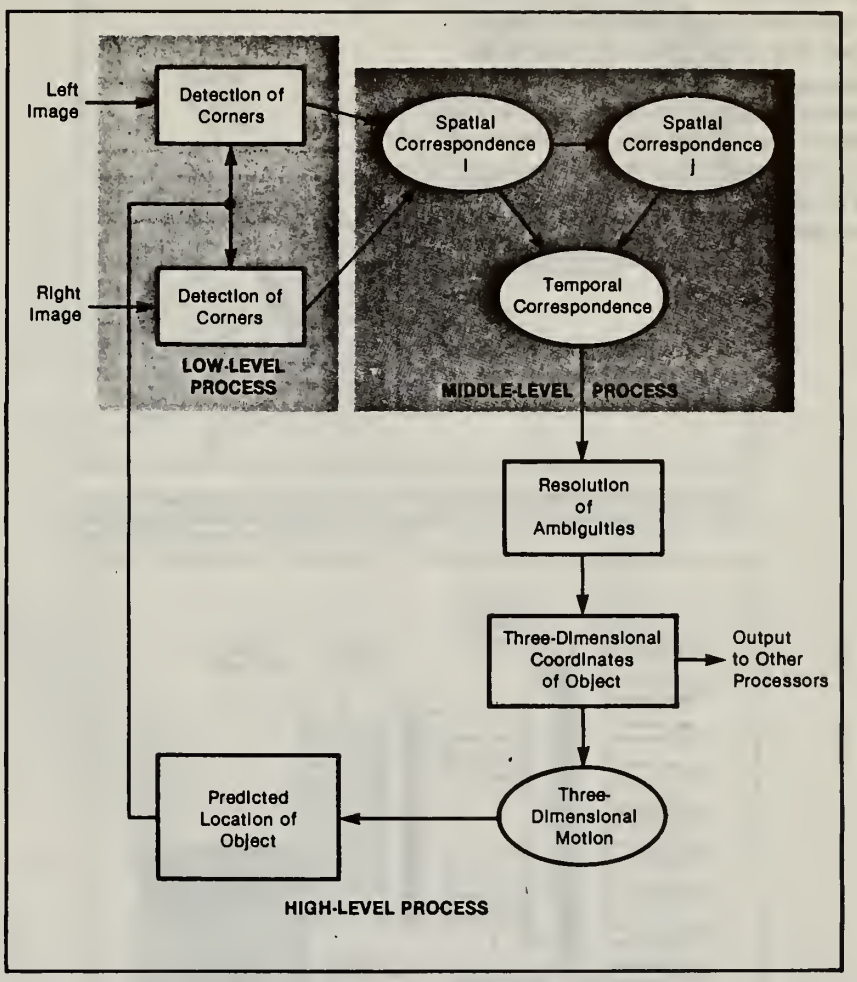


Figure 1. This **Digital Image-Processing System** would act as an "intelligent" automatic machine-vision system by processing views from stereoscopic television cameras into three-dimensional coordinates of a moving object in view.

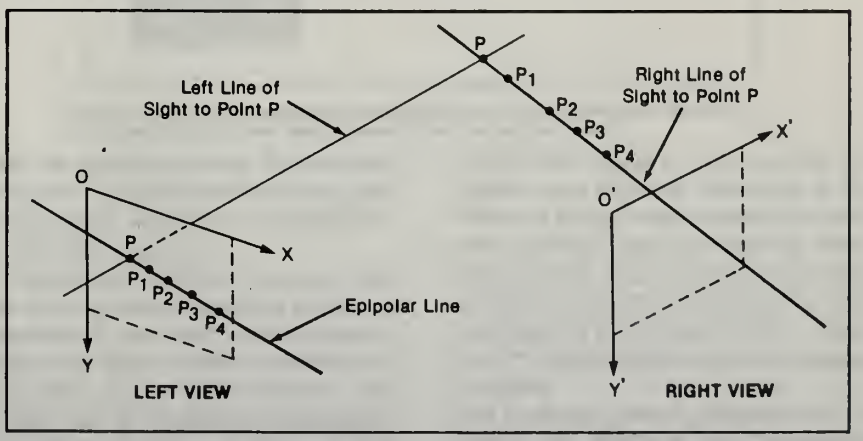


Figure 2. The **Epipolar-Line Technique** would be used to find corresponding points in stereoscopic views. Points close to the epipolar line in the left view are tentatively identified as corresponding to points on the line of sight in the right view.

and consistent correspondence for each pair of successive images. In the first step, matching points would be required to satisfy both spatial and temporal correspondences. In the second step, matching points would be required to exhibit the least deviation from rigidity.

Once the final correspondence is established, the corner points in three-dimensional space could be determined easily as the intersections of the lines of sight to the points in the right and left views. The motion of the object could then be estimated as an affine transformation that uses the least-squares method based on the computed points of the object in two consecutive frames.

This work was done by Thinh V. Nguyen of Multisignal Technology Corp. for **Marshall Space Flight Center.**
MFS-27191/TN

NASA Tech Brief
National Aeronautics and Space Administration
NASA's Jet Propulsion Laboratory, Pasadena, California

Thermal Brushes for Memory-Metal Actuators

Thermal brushes would remove or add heat for rapid actuation.

Proposed thermoelectric elements with wire-brush contacts would remove heat from or add heat to memory-metal actuators and thereby enable them to respond faster than previously possible. A memory-metal actuator is formed to a shape while hot, then to another shape while cold. When a cold actuator is heated so that its temperature rises above a critical point, it snaps from its cold shape to its hot shape. Upon cooling, the actuator returns to its cold shape, ready for another cycle. Clearly, the faster the actuator can be heated and cooled, the faster it can operate.

In an early version of a memory-metal actuator, actuation time was kept short by keeping the actuator just below its critical temperature and passing an electrical current through it for direct resistance heating. Later versions used thermoelectric cooling. Peltier junctions consisting of metal wires were placed on the actuators or on their mounting plates. However, metal thermocouples are highly inefficient and would accomplish little more than transmit heat by conduction. Semiconducting Peltier junctions are orders of magnitude more efficient, but unlike metal wires, they are inflexible. To allow for this inflexibility, a brush contact is employed.

In the proposed configuration, the actuator could still be heated by passing a current through an electrical resistance. However, it could also be both cooled and heated thermoelectrically via a brush mounted on an external thermoelectric heating or cooling plate (Figure 1). The flexible bristles of the brush would press against or could be permanently attached to the actuator, ensuring good thermal contact. Heat would flow rapidly to or from the actuator metal, through the bristles and heating/cooling plate, from or to a heat sink.

Depending on the heating and cooling needs of the device, additional brushes and cooling elements could be placed along the circumference of the actuator. The bristles should bend slightly when they are in contact with the contracted (hot) actuator; they can then easily bend further when the actuator expands. The elements should not be placed near the moving end of the actuator, where they would interfere with the displacement.

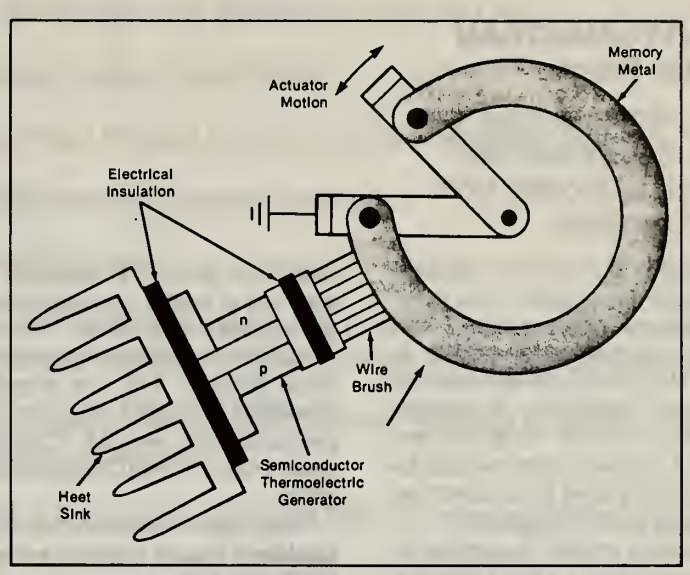


Figure 1. **Mounted In the Plane** of actuator motion, bristles of a metal brush press lightly but firmly against the actuator in its closed (hot) position. When the actuator expands to its cold position, the brushes are compressed further.

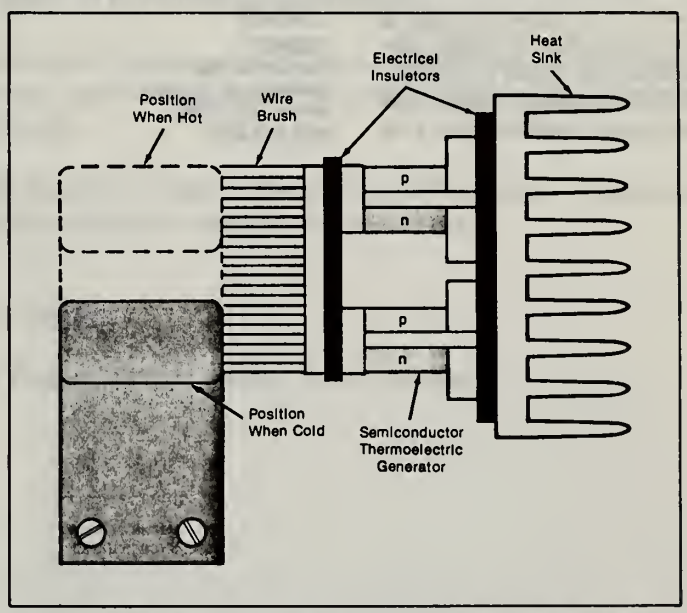


Figure 2. **Mounted Perpendicularly to the Plane** of motion, bristles rub against the sides of the actuator. They maintain thermal contact in both hot and cold states.

The bristles must not be too long or else their thermal resistance will be excessive. Therefore, if they must accommodate a large swing of the actuator, another brush orientation should be considered. The brushes can be mounted perpendicularly to the plane of motion so that they wipe the sides of the actuators as they expand and contract (see Figure 2). In this position, the brushes add frictional resistance to the motion of the actuator; whereas in the in-plane position, they add bending resistance. In either case, the resistance is small compared with the density of the force generated by the memory metal — about 6×10^4 psi (400 MPa) for Nitinol (or equivalent) alloy.

This work was done by Charles Wood of Caltech for **NASA's Jet Propulsion Laboratory**. *NPO-17068/TN.*

FOR ADDITIONAL INFORMATION: *Contact: Director, Technology Transfer Division, P.O. Box 8757, BWI Airport, MD 21240; (301) 621-0100 Ext. 241*
REFER TO THE NUMBER LISTED AT THE END OF THIS ARTICLE

NASA Tech Brief
National Aeronautics and
Space Administration

AutoCAD-To-NASTRAN Translator Program

This program facilitates the creation of finite-element mathematical models from geometric entities.

The AutoCAD to NASTRAN translator (ACTON) computer program was developed to facilitate quick generation of small finite-element mathematical models for use with the NASTRAN finite-element modeling program. (NASTRAN is available from COSMIC.) ACTON reads the geometric data of a drawing from the Data Exchange File (DXF) used in AutoCAD and other PC-based drafting programs.

The geometric entities recognized by ACTON include POINT's, LINE's, SOLID's, 3DLINE's, and 3DFACE's. From this information, ACTON creates a NASTRAN bulk data deck, which can be used to create a finite-element model. The NASTRAN elements created include CBAR's, CTRIA's, CQUAD4's, CPENTA's, and CHEXA's. The bulk data deck can be used to create a full NASTRAN deck. It is assumed that the user has at least a working knowledge of AutoCAD and NASTRAN.

ACTON was written in Microsoft QuickBasic (Version 2.0). The program was developed for the IBM PC and has been implemented on an IBM PC-compatible under DOS 3.21. ACTON was developed in 1988.

This program was written by A. Jones of **Goddard Space Flight Center.**
GSC-13217/TN

FOR ADDITIONAL INFORMATION

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(404) 542-3265

Materials

0972 1989 Annual Directory Published for NVLAP Labs

0973 Predicting Service Life of Paints

0974 Laser-Driven Process Etches Chemically Resistant Surfaces

0975 Sunlight Destroys Hazardous Waste

0976 Joining Ceramics

0977 Deposition of Pinhole-Free $CoSI_2$ Film—A stoichiometric combination of cobalt and silicon is overlaid with silicon. (Licensing Opportunity)

0978 Glass Coats for Hot Isostatic Pressing—Surface voids would be sealed from pressurizing gas.

0979 Making a Superconductive Thin Film—A sharp transition is obtained at 93 K.

0980 Molecular-Beam Epitaxy of $CrSI_2$ on Si(111)—Crystalline layers have been grown in a commercial apparatus.

0981 Resistance to Delamination in Composite Materials—A fracture-mechanics approach is applied to delamination failures. (Licensing Opportunity)

0982 Unified System of Data on Materials and Processes—Wide-ranging sets of data for aerospace industry are described.

Other Items of Interest

0950 Rapid Process Makes Energy-Smart Windows

NIST Technology Update

National Institute of Standards & Technology
(Formerly the National Bureau of Standards)
U.S. Department of Commerce, Gaithersburg, MD 20899

1989 Annual Directory Published For NVLAP Labs

The 1989 Directory of NVLAP Accredited Laboratories (NISTIR 89-4056), lists 200 labs nationwide and abroad that are accredited by NIST for specific test methods in various fields of testing as of Apr.1, 1989. The current fields are acoustics; carpet; commercial products - paint, paper, plastic, and seals and sealants; computer protocols; construction testing services - concrete, cement, aggregates, soil and rock, admixtures, geotextiles, road and paving; personnel radiation dosimetry; electromagnetic compatibility and telecommunications; solid fuel room heaters; and thermal insulation. The labs are listed alphabetically by name, field of testing, and state.

FOR ADDITIONAL INFORMATION: A copy of the report is available from NTIS, Springfield, VA 22161; (703)487-4600.

NTIS order number: PB 89-189278/NAC

Price code: A05

For Information on NVLAP programs, including the new bulk asbestos analysis program, contact: National Voluntary Laboratory Accreditation, NIST, A 124 Bldg. 411, Gaithersburg, MD 20899; (301)975-4016.

NIST Technology Update

National Institute of Standards & Technology
(Formerly the National Bureau of Standards)
U.S. Department of Commerce, Gaithersburg, MD 20899

Predicting Service Life of Paints

Does a change in the appearance of paint, such as fading, chalking, or yellowing, mean the coating can no longer protect the base material? Not necessarily, found researchers in the NIST Center for Building Technology in a review of the technical literature. For the past several years, NIST has been investigating ways to predict the "service life" of building materials, including coatings. Knowing how long a material will remain serviceable can help in selection and use and in developing cost-effective maintenance strategies. But no quantitative test method exists to predict durability of coatings, and questions have been raised whether changes in appearance can be used as early indicators that the coating is deteriorating. The NIST researchers concluded that changes in appearance are not necessarily related to changes in the protective properties of a coating.

FOR ADDITIONAL INFORMATION: A report, Relationship Between Appearance and Protective Durability of Coatings: A Literature Review (NISTIR 88-4010), is available from NTIS, Springfield, VA 22161; (703)487-4600.

NTIS order number: PB 89-162598/NAC
Price code: A05

Sandia National Laboratory

Laser-Driven Process Etches Chemically Resistant Surfaces

A new laser-driven process for etching chemically resistant materials has been developed at Sandia National Laboratories. The process is faster and more flexible than other methods.

Carol Ashby, Jerry Brannon, and Jim Gerardo of Sandia's Laser and Chemical Physics Research Department developed the process with lithium niobate, a chemically inert substance used in optical waveguide switches. Such devices, connected to optical fibers, redirect and modulate light waves.

The researchers say a possible application of the process could be the etching of ridges to guide light waves through the switches. This is the first application of a laser-driven chemical fusion reaction to etch a substrate, and it could be adapted for use on other inert materials. For example, lithium tantalate, a substrate material with properties similar to lithium niobate, is one of the substances that could be etched using the method, Ashby says.

The process involves coating the substrate with powdered potassium fluoride and then directing laser pulses onto the area to be etched. The heat is sufficient to melt the lithium niobate. This permits the two substances to chemically react and form a nontoxic water-soluble solid containing niobium oxyfluoride anions. Such reactions of molten salts are called fusion reactions. Since the untreated area of the lithium niobate remains insoluble, etching is accomplished by simply rinsing the irradiated, soluble area from the substrate with water.

Although lithium niobate sometimes cracks when heated rapidly, no evidence of this problem was found by the Sandia researchers during their experiments.

Ashby, Brannon, and Gerardo have demonstrated the principle of the new method, but they have not used the method for device fabrication. Further development of the method with a stable laser will be required before employing it for full-scale fabrication of devices.

Current techniques for making holes and grooves in substrates - either by ion etching or ion beam milling - are much slower than the laser-driven technique developed by the Sandia researchers. Ashby, Brannon, and Gerardo achieved etching rates in excess of 10 microns per minute compared to rates of approximately .01 to .05 microns per minute using the other methods.

While mechanical techniques such as ultrasonic impact grinding are as fast as the laser-driven chemical reaction method, they are limited to indentations of at least a millimeter in width. The lateral resolution of the laser-driven fusion process has not been determined experimentally, but, like other laser-driven thermal processes, it is expected to be on the order of the laser spot size (about 1 micrometer or slightly less).

Flexibility in design is another advantage of the laser-driven method, Ashby explains.

"With mechanical methods, you are really restricted in size. With other methods, you have to mask the area that you don't want to etch," she explains. "With the laser-driven method, you can tailor your beam and focus the light to control the melting."

Experimental studies centered on the identification of a method for depositing laser energy most efficiently at the point where the chemical reaction occurs - at the interface between the substrate and the powdered coating. The Sandia researchers used three different laser wavelengths of 355 nanometers, 270 nanometers, and 248 nanometers. The 355-nanometer light produced no reaction since its photons penetrated too deeply into the substrate. At the other wavelengths, most of the energy was deposited very near the surface of the lithium niobate, where melting and fusion created the soluble substance.

With both of the shorter wavelengths, greater etch depths for a given number of pulses were achieved as the laser power was increased. At constant power with the 270-nanometer laser, successive pulses etched deeper into the substrate. However, etched depths were not increased by successive pulses of the 248-nanometer laser.

The Sandia researchers explain that the 270-nanometer laser achieved greater etched depths because its photons did not deposit their energy in the growing layer of oxyfluorides lying on top of the substrate, and each successive pulse produced further melting below the substrate surface. The 248-nanometer laser deposited its energy in the layer of the product oxyfluorides and melting occurred repeatedly at the same depth from the surface.

Although the 270-nanometer laser is mot effective on lithium niobate, other substances may have absorption coefficients better suited to longer or shorter wavelengths, Ashby says.

Using the 248-nanometer wavelength, Ashby, Brannon, and Gerardo also compared the process with direct laser ablation - simply eroding the lithium niobate substrate with a laser beam. They found the laser-driven chemical etching process to be superior to direct ablation because the ablated holes had greater debris accumulation. The ablated holes had debris around them that was 10 to 50 percent as high as the hole depths. In contrast, the chemically etched holes had no debris on their edges.

This smoothness would be advantageous in producing accurate lenses and grooves used in waveguides. The smooth surfaces were achieved at lower laser power. Higher power resulted in vaporization of the potassium fluoride before it could react with the lithium niobate, creating rougher surfaces like those found in the directly ablated holes.

FOR ADDITIONAL INFORMATION: Public Information Division, Code 3161, Department of Energy, Sandia National Laboratories, Albuquerque, NM 87185-5800; (505)844-4207. Refer to announcement 24, No. 6.

Solar Energy Research Institute

Sunlight Destroys Hazardous Waste

Experiments at SERI have shown that hazardous wastes such as textile dyes and industrial solvents can be destroyed in an innovative, one-step process called solar photocatalytic conversion.

In this process, sunlight is concentrated on a receiver tube in which contaminated water and a suspended catalyst are circulated. The catalyst absorbs high-energy photons, forming reactive chemicals that convert toxic wastes into harmless or more easily neutralized byproducts such as dilute hydrogen chloride or carbon dioxide.

SERI researchers are using a receiver tube mounted on a parabolic trough concentrator to destroy textile dye Direct Red No. 79. Results are dramatic. After a 15-minute exposure to intense sunlight, the dye vanishes as concentrations drop from 100 parts per million (ppm) to less than 5 ppm—a remarkable 95% destruction efficiency.

The process is being optimized by analyzing the effect of different catalysts, temperatures, and acidity.

Experiments are continuing with trichloroethylene (TCE), a car-

SERI's parabolic trough concentrator destroys hazardous wastes such as textile dyes and solvents.

cinogenic solvent often found in drinking water. Indoor tests with a solar simulator indicate that TCE concentrations of 100 ppm can be reduced to less than 50 parts per *billion* using the photocatalytic process.

These experiments are part of a DOE Solar Thermal Program initiative to develop innovative ways of destroying hazardous waste. SERI and Sandia National Laboratories are participating in the joint research and development project.

For Additional Information:

John Thornton
Solar Energy Research Institute
1617 Cole Boulevard
Golden, CO 80401-3393
(303) 231-1269

Refer to Volume XI, Number 2/TN

Joining Ceramics

A factor that could restrict the use of ceramic materials in high-performance applications such as advanced heat engines or heat exchangers is the ability to reliably join ceramic components to form complex assemblies, or to join unit lengths of ceramic material to form ceramic systems. A new filler for the direct brazing of metals and ceramics to themselves and one another has been developed at the Oak Ridge National Laboratory. Two types of brazing processes are used to join ceramics.

For indirect brazing, the ceramic is coated with a metal such as molybdenum or titanium prior to brazing with a nonreactive commercial filler metal. The metallizing used in this process is complicated and expensive, and the strength of the coating-ceramic bond and the corrosion resistance of the coating are of concern. Direct brazing, in which ceramics are joined using a filler metal specially formulated to wet and bond the ceramics, is preferred because it avoids these problems. The new alloy is in the composition range 35-50 at. % Cu, 40-50 at. % Ag, 1-15 at. % Ti, and 2-8 at. % Sn. This filler metal will wet, and bond to, ceramics and metals, and will withstand high service temperatures. Tin is present in sufficient quantity to lower the alloy's melting point without causing embrittlement. Tin also enhances the wetting characteristics of the alloy and reduces the amount of titanium needed. Some other direct brazing alloys must be used above 1000 degrees C, at which temperatures certain metals can experience microstructural transformations. However, the new Oak Ridge National Laboratory alloy can be used at temperatures below 850 degrees C, thus making it possible to directly braze thermally sensitive materials such as nodular cast iron and partially stabilized zirconia without damage to either material. In addition to the advantage offered by its low melting point, this alloy contains less silver and produces stronger joints than other Cu-Ag-Ti brazing alloys.

For more information contact James R. Weir (615) 574-4064.

NASA Tech Brief
National Aeronautics and Space Administration

Licensing Opportunity

NASA's Jet Propulsion Laboratory, Pasadena, California

Deposition of Pinhole-Free $CoSi_2$ Film

A stoichiometric combination of cobalt and silicon is overlaid with silicon.

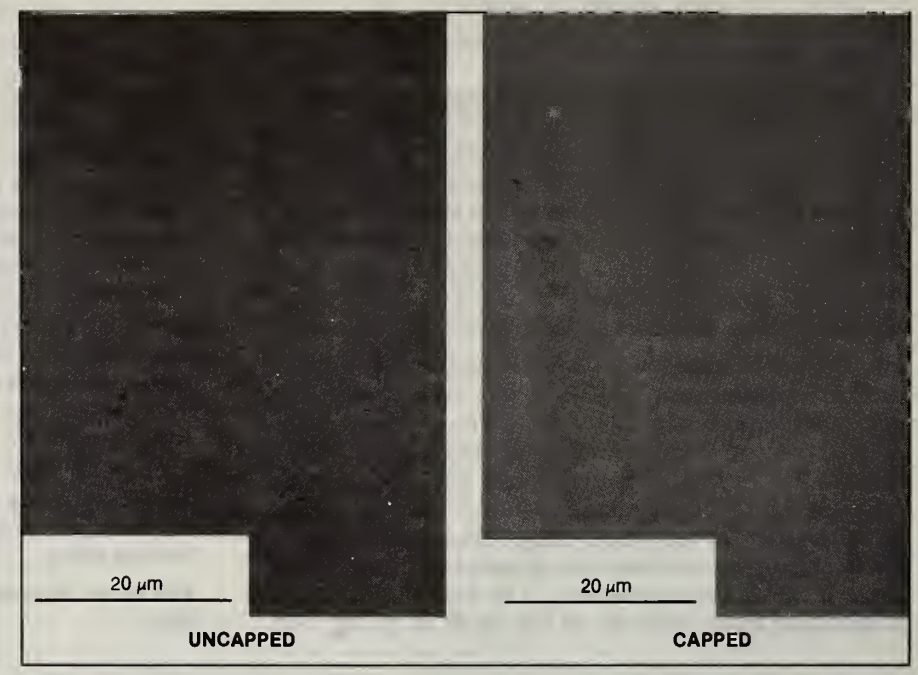
A new fabrication method produces a pinhole-free film of cobalt silicide on a silicon substrate. Earlier methods resulted in as many as 10^7 pinholes per square centimeter. The absence of pinholes is critical to the operation of multilayer devices employing $CoSi_2$ layers, such as the metal base transistor.

In the new method, cobalt and silicon are evaporated from electron-beam sources onto a substrate of silicon having a <111> crystal orientation. The materials are deposited in the stoichiometric ratio of two silicon atoms to one of cobalt, yielding a single-crystal $CoSi_2$ film 5 to 10 nm thick. A layer of amorphous silicon 1 to 2 nm thick is deposited on the $CoSi_2$. The specimen is then annealed at 550 °C for 10 min.

The amorphous-silicon cap prevents pinholes from forming during annealing. In the absence of this cap, apparently the high surface energy of $CoSi_2$ relative to Si causes the formation of pinholes, which expose the underlying Si surface and thereby reduce the total energy of the epitaxial system at temperatures above 500 °C. The silicon cap appears to reduce the total surface energy without the formation of pinholes. In fact, the temperature can be raised as high as 600 °C with the cap.

Because the $CoSi_2$ layer is stoichiometric, it does not consume the cap during annealing. Thus, the cap remains during the entire annealing process and is available to serve as a template for further deposits of silicon during later processing.

Scanning electron microscopy and other techniques were used to evaluate the quality of the $CoSi_2$ films on both silicon-capped and uncapped substrates. The films were etched with carbon tetrafluoride plasma to enlarge pinholes for greater visibility; where a silicon cap layer covered a pinhole, it, too, was removed by the plasma. This procedure improved the detection resolution to 1,000 pinholes per square centimeter. No pinholes could be found on the capped film, whereas the uncapped film was riddled with pinholes (see figure).



The Scanning Electron Micrograph of a silicon-capped $CoSi_2$ film shows no pinholes, whereas that of an uncapped film shows many. The density of pinholes in the micrograph of the uncapped specimen is 2×10^7 cm^{-2}. Both the capped and uncapped specimens have been etched by CF_4 plasma to enhance the visibility of the pinholes.

This work was done by True-Lon Lin, Robert N. Fathauer, and Paula J. Grunthaner of Caltech for **NASA's Jet Propulsion Laboratory.**

In accordance with Public Law 96-517, the contractor has elected to retain title to this invention. Inquiries concerning rights for its commercial use should be addressed to

Edward Ansell
Director of Patents and Licensing
Mail Stop 305-6
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Refer to NPO-17447/TN.

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FOR ADDITIONAL INFORMATION: *Contact: Director, Technology Transfer Division, P.O. Box 8757, BWI Airport, MD 21240; (301) 621-0100 Ext. 241*
REFER TO THE NUMBER LISTED AT THE END OF THIS ARTICLE

NASA Tech Brief
National Aeronautics and Space Administration
Marshall Space Flight Center, Alabama

Glass Coats for Hot Isostatic Pressing

Surface voids would be sealed from pressurizing gas.

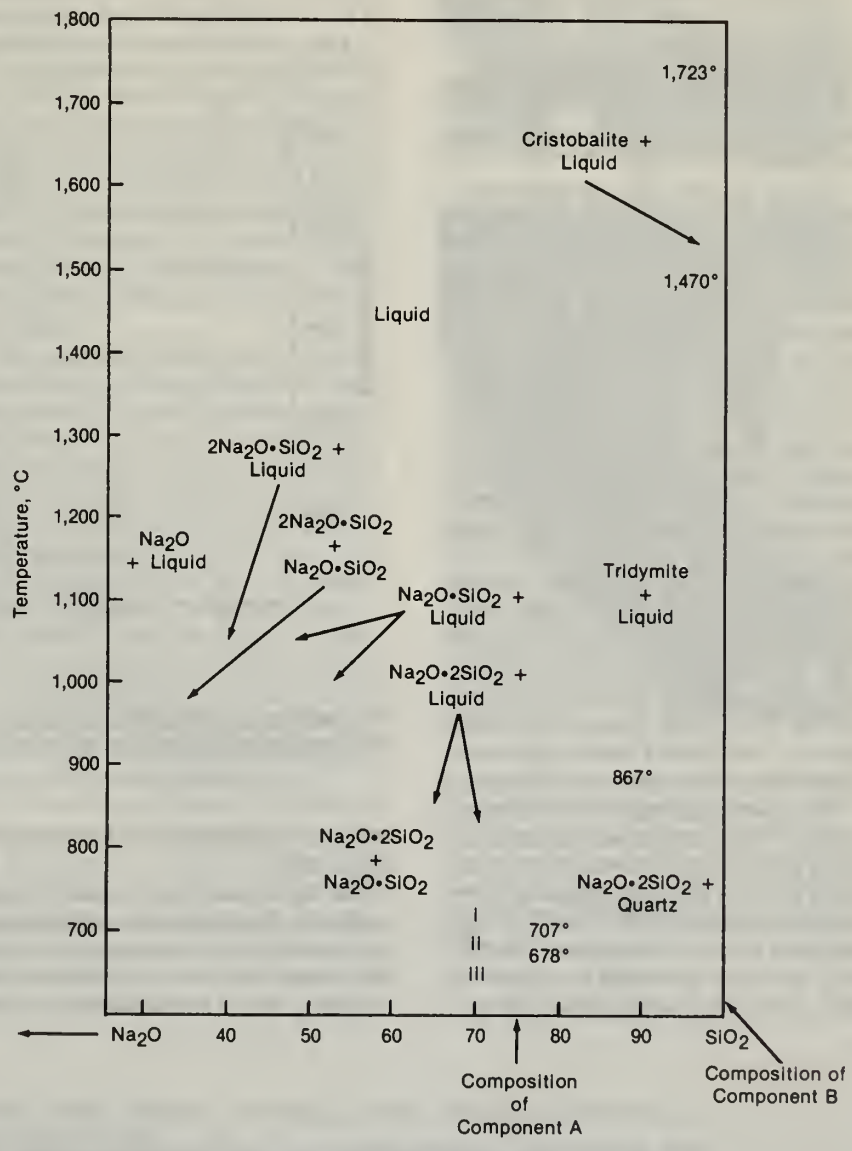
A proposed coating technique would enable the healing of surface defects by hot isostatic pressing (HIP). Internal pores are readily closed by HIP, but surface voids like cracks and pores that are in contact with the pressurizing gas are not healed. The proposed coat would be easy to apply, would separate the voids from the surrounding gas, would not react with the metal part under treatment, and would be easy to remove after pressing.

The coat would be applied to a casting or weldment as a thick slurry of two glass powders: one (component A), which melts at a temperature slightly lower than that used for HIP, and another (component B), which melts at a higher temperature. For example, powder A could be a glass of 75 percent SiO_2 and 25 percent Na_2O, while the other powder could be SiO_2 (see figure). The liquid component of the slurry could be a fugitive organic binder; for example, a mixture of cellulose acetate and acetone.

Most casting defects at surfaces occur in "hotspots" — areas where heat is not conducted away fast enough during solidification. Such areas are often inaccessible. The slurry should readily flow to them, however, after being brushed on a casting. The user does not have to worry about applying too much slurry — it should come off easily after HIP.

In the case of the Na_2O/SiO_2 material mentioned above, as the temperature is raised to about 825 °C during hot isostatic pressing, the lower-melting glass should first melt; but then the glasses should react, and the melting point should rise so that the glass mixture should harden. With the proper choice of the relative amounts of each glass, the mixture should form a coat stiff enough to protect against the gas pressures of 15,000 lb/in.^{2} (100 MPa) typically used in HIP.

When pressing is complete, the casting would be cooled to room temperature. The glass coat should shrink faster than the casting would. Therefore, the coat should spall from the casting, leaving no detectable effects on it.



The **Phase Diagram of Na_2O and SiO_2** indicates that a glass that has a melting temperature between ~780 and 1,723 °C can be made by mixing various proportions of 75-percent SiO_2/25-percent Na_2O glass with pure SiO_2. The numbers on the horizontal axis denote weight percentages of SiO_2.

This work was done by Gunes M. Ecer of Rockwell International Corp. for **Marshall Space Flight Center.**

MFS-29501/TN

FOR ADDITIONAL INFORMATION: *Contact: Director, Technology Transfer Division, P.O. Box 8757, BWI Airport, MD 21240; (301) 621-0100 Ext. 241*
REFER TO THE NUMBER LISTED AT THE END OF THIS ARTICLE

NASA Tech Brief
National Aeronautics and Space Administration
Marshall Space Flight Center, Alabama

Making a Superconductive Thin Film

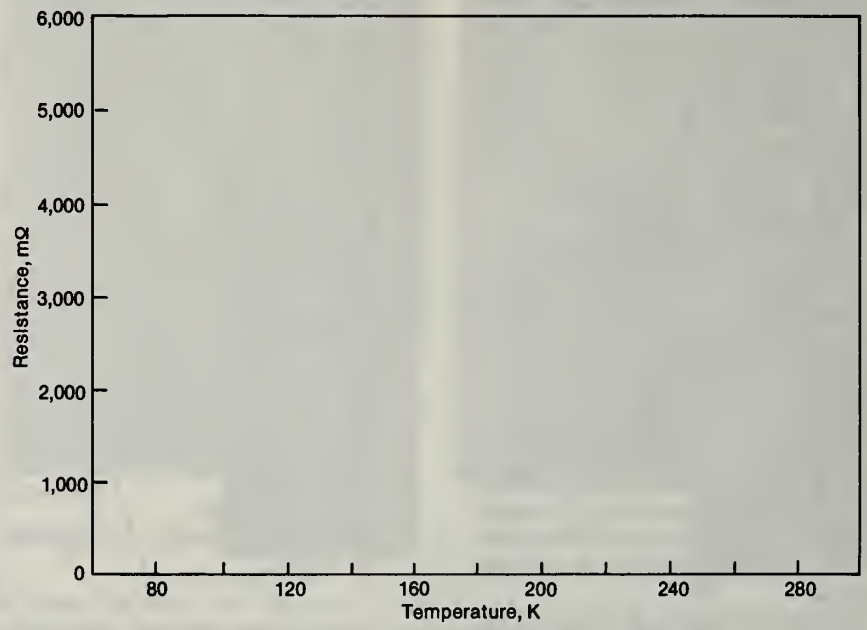
A sharp transition is obtained at 93 K.

An experimental fabrication process results in a superconductive thin film of $YBa_2Cu_3O_7$ (the "123" phase of Y/Ba/Cu/O) on a substrate of green semiconducting Y_2BaCuO_5 (the "211" phase). The film becomes superconductive below a transition temperature (T_c) of 93 K.

Previous experiments had shown that after specimens of Y/Ba/Cu/O were reacted at temperatures greater than 950 °C but for relatively short times, they had sharper T_c transitions. This observation gave rise to the hypothesis that an extremely careful heat treatment is necessary because the formation of the semiconducting "211" phase is thermodynamically favored over the formation of the superconducting "123" phase. The new fabrication process takes account of this hypothesis by incorporating suitable heat treatments.

In the experiment, preparation of the semiconducting substrate material was begun by grinding appropriate amounts of metal oxides, pressing them into pellets, then heating them to 950 °C for 12 h to form the "211" phase. To assure complete reaction, the pellets were reground, pressed into pellets again, and reheated.

The superconducting material to be deposited on the substrate was prepared by mixing the appropriate amounts of metal oxides to form $YBa_2Cu_3O_7$, pressing them into pellets, heating at 950 °C for 12 h, then quenching to room temperature. The material was then annealed in oxygen at 950 °C for 6 h, followed by slow cooling in the furnace. At this point, the material had a T_c of 96 K.



The **Resistance of the Film** deposited by the experimental fabrication process decreases with decreasing temperature down to 93 K, where it exhibits a sharp transition to zero.

The superconducting material was deposited on the substrate by radio-frequency sputtering at room temperature. Initially, the deposited film was 1 mm thick and was insulating. After it was annealed in oxygen at 900 °C for 30 min, then cooled in the furnace, it had become superconducting. As shown in the figure, the transition to superconductivity at 93 K is very sharp. The estimated critical current density is 350 A/cm^2.

This work was done by Maw-kuen Wu of the University of Alabama for **Marshall Space Flight Center.** *MFS-26093/TN.*

FOR ADDITIONAL INFORMATION: *Contact: Director, Technology Transfer Division, P.O. Box 8757, BWI Airport, MD 21240; (301) 621-0100 Ext. 241*
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NASA Tech Brief
National Aeronautics and Space Administration
NASA's Jet Propulsion Laboratory, Pasadena, California

Molecular-Beam Epitaxy of $CrSi_2$ on Si(111)

Crystalline layers have been grown in a commercial apparatus.

Experiments have shown that $CrSi_2$ can be grown on the (111) face of a single-crystal Si substrate by molecular-beam epitaxy. The epitaxial $CrSi_2$ produced thus far is not in the desired single-crystal form. However, because $CrSi_2$ is a semiconductor with a band gap of 0.3 eV, the experimental process has potential for the monolithic integration of microelectronic devices based on $CrSi_2$ (e.g., infrared detectors) with signal-processing circuitry based on Si.

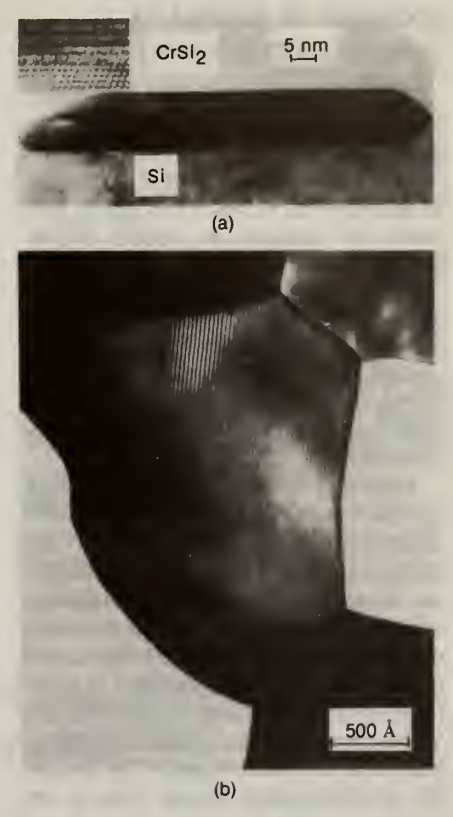
In the experiments, Si(111) wafers were first cleaned chemically by a process that leaves a protective oxide on the surface. The wafers were then placed in a commercial molecular-beam epitaxy (MBE) apparatus, where the oxide was removed by a beam of Si in some cases or by thermal desorption in other cases.

The apparatus was equipped with separate electron-beam evaporators, one for Si and one for Cr. Each $CrSi_2$ specimen was grown by one of four techniques, each of which is a special case of generic MBE. In the first technique, called "solid-phase reactive epitaxy" (SRE), Cr was deposited on a subtrate of Si held at room temperature; the substrate and deposit were then annealed at a temperature of 580, 650, or 720 °C. In the second technique, called "reactive-deposition epitaxy" (RDE), Cr was deposited on a hot Si substrate. The third technique, called "solid-phase epitaxy" (SPE), involved the stoichiometric deposition of Cr and Si at room temperature, followed by annealing at higher temperature. In the fourth technique, denoted by the generic term "MBE," Cr and Si were codeposited stoichiometrically on a hot Si substrate.

$CrSi_2$ layers were grown to thicknesses of 10 and 210 nm (see figures). The specimens were monitored during growth by reflection high-energy electron diffraction (RHEED). After removal from the MBE apparatus, the specimens were analyzed by scanning electron microscopy (SEM), transmission electron microscopy (TEM), and Rutherford backscattering spectroscopy (RBS).

The analyses showed that the $CrSi_2$ layers tended to form islands, within each of which one of several crystalline orientations prevailed. The two most common orientations observed were $CrSi_2(0001)//Si(111)$ with $CrSi_2[10\bar{1}0]/Si[10\bar{1}]$ and $CrSi_2(0001)/Si(111)$ with $CrSi_2[11\bar{2}0]/Si[10\bar{1}]$. The two orientations differ in that the $CrSi_2$ layers are rotated about 30° with respect to each other about the perpendicular to the surface. For the thick layers, the MBE technique yielded the largest grains and best RHEED pattern. The sizes of the grains were found to increase with temperature: grains 1 to 2 μm across were observed in a layer deposited at 825 °C.

This work was done by Robert W. Fathauer, Paula J. Grunthaner, True-Lon Lin, and David N. Jamieson of Caltech and Jurek H. Mazur of USC for **NASA's Jet Propulsion Laboratory.** *NPO-17438/TN*



Micrographs of $CrSi_2$ Layers show (a) cross-sectional TEM image of an island of $CrSi_2$ for a 10-nm layer grown by SRE. The insert shows the latice image of a portion of the $CrSi_2$/Si interface. Part (b) is a planar TEM image of a 210-mm layer grown by MBE.

FOR ADDITIONAL INFORMATION: *Contact: Director, Technology Transfer Division, P.O. Box 8757, BWI Airport, MD 21240; (301) 621-0100 Ext. 241*
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NASA Tech Brief
National Aeronautics and Space Administration

Licensing Opportunity

Resistance to Delamination in Composite Materials

A fracture-mechanics approach is applied to delamination failures.

Delamination is the most-commonly-observed mode of failure in composite-material dynamic components of rotorcraft. Potential delamination sites in composite structures exist at discontinuities in load paths; for example, at straight edges, bonded joints, and bolted joints. These discontinuities give rise to interlaminar stresses even when the remote loading is in the plane of the laminations. Clearly, it would be useful to be able to model delamination mathematically and predict its onset for a given loading condition at a specified discontinuity.

A report presents a fracture-mechanics approach to analyzing, characterizing, and designing against delamination. In the study, examples of delamination problems are illustrated wherein the strain-energy-release rate associated with the growth of delamination has been found to be a useful generic parameter, independent of thickness, layup, and source of delamination, for the characterization of failure by delamination. Several techniques for the calculation of strain-energy-release rates for delaminations from a variety of sources are outlined. A technique for the quantification of durability due to cyclic loading is presented.

One example of this approach is the analysis of edge delamination. In this case, the strain-energy-release rate is related through an equation to the remotely applied strain, the thickness of the laminate, and the modulus of the laminate with and without the delamination. The strain-energy-release rate is independent of the size of the delamination and the orientation of the layup. A critical strain for delamination is identified, and this is used to calculate a critical strain-energy-release rate, which is then used to calculate the remotely applied strains required to propagate a delamination for a number of different fiber orientations. These predictions, for the case of edge delamination, closely approximate experimentally-determined strain values.

To model delaminations involving mixed-mode fracture, a finite-element approach is used to calculate the three components of the strain-energy-release rate: G_I (interlaminar tension), G_{II} (interlaminar sliding shear), and G_{III} (interlaminar scissoring shear). The total G is then determined by summing these components. This technique can be applied to different geometries, calculating the strain-energy-release rate components for several different sources of delamination.

This work was done by T. Kevin O'Brien of **Langley Research Center**. *"Delamination Durability of Composite Materials for Rotorcraft."*

This invention is owned by NASA, and a patent application has been filed. Inquiries concerning nonexclusive or exclusive license for its commercial development should be addressed to the Patent Counsel, Langely Research Center. Refer to LAR-13753/TN.

Ames Research Ctr.
Technology Utilization Officer: Laurance Milov
Mail Code 223-3
Moffett Field, CA 94035
(415) 694-4044
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(415) 694-5104

FOR ADDITIONAL INFORMATION: *Contact: Director, Technology Transfer Division, P.O. Box 8757, BWI Airport, MD 21240; (301) 621-0100 Ext. 241*
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NASA Tech Brief
National Aeronautics and
Space Administration

Unified System of Data on Materials and Processes

Wide-ranging sets of data for aerospace industry are described.

A document describes the Materials and Processes Technical Information System (MAPTIS), a computerized set of integrated data bases for use by NASA and the aerospace industry. MAPTIS stores information in a standard format for fast retrieval in searches and surveys of data. It helps engineers select materials and verify their properties. It promotes standardized nomenclature as well as standardized tests and presentation of data.

MAPTIS contains the following sets of data, among others:

- Nonmetallic materials — specifications, manufacturers, trade names, flammability, toxicity, and compatibility with hydrazine, hydraulic fluid, oxygen, and hydrogen.
- Metals — alloys, heat treatments, corrosion, stress corrosion cracking; and compatibility with oxygen, nitrogen tetroxide, hydrazine, hydrogen, and hydraulic oil.
- Atomic oxygen — effects on materials, guidelines for selection, and protective techniques.
- Thermal vacuum stability — data on outgassing, gathered from a variety of agencies.
- Verification and control of materials — information on where materials are used, ready reference for foreign alloys, and records of agreements on the uses of materials.
- Properties of materials, including mechanical, electrical, chemical, and thermal properties — particularly those related to processing, safety, and endurance in use.
- Lubricants — lubricity, viscosity, temperature range, formulation, flashpoint, chemical properties, processing, and thermal properties.
- Specifications and standards.

The format of the document is that of photographic projection slides used in lectures. The document presents examples of reports from the various data bases.

This work was done by Carlo F. Key of EER Sytems for **Marshall Space Flight Center**. *"Materials and Processes Information System."*
MFS-27212/TN

FOR ADDITIONAL INFORMATION: *Contact: Director, Technology Transfer Division, P.O. Box 8757, BWI Airport, MD 21240; (301) 621-0100 Ext. 241*
REFER TO THE NUMBER LISTED AT THE END OF THIS ARTICLE

Medicine & Biology

0983 Development of Statistical Distributions or Ranges of Standard Factors Used in Exposure Assessments

0984 Clinical Instruments can be Sterilized in Seconds (Licensing Opportunity)

0985 Animal Cell Culture Collection

0986 Mouse Mutant Gene Resource

0987 Bacteriology Collection

0988 Animal Models for Comparative Medical Research

Software

0989 Computer System Rapidly Analyzes Sperm Movement

United States
Environmental Protection
Agency

Office of Health and
Environmental Assessment
Washington DC 20460

Research and Development

EPA

Project Summary

Development of Statistical Distributions or Ranges of Standard Factors Used in Exposure Assessments

This summary provides information on how to calculate human exposure to toxic substances and ranges of values for body weight, skin surface area, and ventilation rates.

Percentile distribution of body weight were computed from the Second National Health and Nutrition Examination Survey (NHANES II) data base computer program. Distributions of skin surface areas were similarly calculated from NHANES height and weight data by applying regression equations.

Insufficient data precluded the development of distributions of ventilation rates. Activity pattern information is presented to permit the calculation of time-weighted average ventilation rates.

This Project Summary was developed by EPA's Office of Health and Environmental Assessment, Washington, DC, to announce key findings of the research project that is fully documented in a separate report of the same title (See Project Report ordering information at back).

Introduction

Using standard factors in exposure assessments promotes consistency among various exposure assessment activities in which the Environmental Protection Agency (EPA) is involved. Consistency with respect to common physical, chemical, and biological factors, to assumptions about typical exposure situations, and to the presentation of the possible ranges of estimates, enhances the comparability of results and encourages gains in state-of-the-art exposure assessment techniques.

Current practice for estimating human exposures typically involves the assumption of average values for such factors as body weight, liquid consumption, and respiration rates. The full report presents statistical distributions or ranges of values for these factors.

Where sufficient data are available, percentile distributions are developed. Where insufficient data precluded the development of statistical distributions, ranges of values were compiled from measurements reported in the literature. In a few instances, unpublished data obtained through correspondence with researchers have been used to develop ranges or distributions. All data, including these unpublished data, are presented in the Appendices of the full report. A glossary of terms is also presented.

Body Weight

Published percentile distributions for body weight for men and women and male and female children are based primarily on data gathered in the first National Health and Nutrition Examination Survey during 1970 and 1974. The source of data used in this study is the more recent, second National Health and Nutrition Examination Survey , NHANES II, for which published percentiles are not yet available.

NHANES II was conducted on a nationwide probability sample of approximately 28,000 persons, aged 6 months to 74 years, from the civilian, noninstitutionalized population of the United States. The survey started in February 1976 and was completed in February 1980. The sample was selected so that certain population groups thought to be at high risk of malnutrition (persons with low incomes, preschool children and the elderly) were oversampled. NHANES II provides information on 20,322 interviewed and examined individuals.

Weight was measured with a scale that mechanically prints weight to quarter-pound intervals directly onto the permanent record.

In the full report, percentiles (and their standard errors) of the distribution of body weight have been computed from the NHANES II data using the computer program QNTLS.

Surface Area of the Human Body

Two approaches can be used to determine the surface area (SA) of the

body: direct measurement of the skin area or estimating the SA by geometrical approximation.

Several direct measurement techniques have been used to measure SA, including direct coating, triangulation, and surface integration.

Ventilation Rates

Pulmonary ventilation data and activity pattern data permit the calculation of time-weighted average ventilation rates.

Pulmonary ventilation is the mass movement of gas in and out of the lungs. The volumes of inhaled and exhaled air usually are not exactly equal; the volume of inspired oxygen is typically larger than the volume of expired carbon dioxide. Pulmonary ventilation is generally represented by the minute volume ($\dot{V}e$), the volume of gas expired in liters per minute at BTPS (gas volume at normal body temperature and ambient barometric pressure, saturated with water vapor). Minute volume is the product of tidal volume (the volume of gas moved during each respiratory cycle) and respiratory frequency.

Minute volume is usually measured accurately with a water-filled spirometer. The spirometer uses one-way valves to funnel expired air into a collection system or alternatively, directly into a spirometer.

There have been several formulae proposed in the literature to calculate minute ventilation of humans at rest from anthropometric data.

Resting ventilation is directly related to the resting metabolic rate. With exercise, minute volume increases in response to the increase in metabolic demand. There is an abrupt increase in ventilation with the onset of exercise, followed by a further, more gradual increase. With moderate exercise, the increase is due primarily to an increase in tidal volume; this is accompanied by an increase in respiratory frequency when the exercise becomes more strenuous. When exercise ceases, there is an abrupt decrease in ventilation, followed by a more gradual decline to preexercise values.

Review of the literature failed to identify equations that would enable the development of statistical distributions of minute ventila-tion at all activity levels for male and female children and adults. Therefore, ranges of measured values were compiled from the available data, which are tabulated in the full report. Many of these measurements are from early studies.

Most of the available minute ventilation measurements are from studies expressing the associated activity levels in terms of kilogrammeters per minute. In other studies, the activity level was given qualitatively by the type of activity (e.g., walking at 3 miles per hour); the associated breathing rates were categorized based on representative activities.

For each age-sex-activity level category for which data were available, minimum, maximum, and mean minute volumes were determined. These values were derived from both individual measurements and reported mean values, for which the raw data were not presented. Weighted means were calculated by assigning each individual measurement a weight of one and each mean value a weight corresponding to the number of subjects the mean represented; the weighted data were then summed and divided by the total number of subjects. The standard deviations for the age-sex-activity level groups were not calculated because many of the mean values used were reported without any measure of distribution variance. In addition, many groups had very few data points, making standard statistical summaries difficult to interpret. In some cases, means were presented without the minimum and maximum values of the original data sets; therefore, the minima and maxima for age-sex-activity level groups are representative only of the available individual measurements.

Activity pattern data may be used in conjunction with minute volume data to estimate ventilation rates. In addition to providing information on exercise levels, available activity pattern studies also describe the amount of time spent in different microenvironments. Such detailed information is desirable if the ambient concentration of a pollutant differs significantly from one microenvironment to another, as may happen with particulate filtration from the outdoor to the indoor microenvironment.

More detailed activity pattern data are available in the Appendices of the full report which presents in its entirety a document describing activity patterns for 56 population subgroups. This document is a supplement to a report on the application of the National Ambient Air Quality Standard Exposure Model to carbon monoxide. Hourly assignments to locations, microenvironments, and activity levels are presented for each population subgroup.

E. Anderson, N. Browne, S. Duletsky, J. Ramig, and T. Warn are with GCA Corporation, Chapel Hill, NC 27514,
Tom McLaughlin is the EPA Project Officer (see below).
The complete report, entitled, "Development of Statistical Distributions or Ranges of Standard Factors Used in Exposure Assessments," (Order No. PB 85-242 667/AS; Cost: $21.95, subject to change) will be available only from:
National Technical Information Service
5285 Port Royal Road
Springfield, VA 22161
Telephone: 703-487-4650
The EPA Project Officer can be contacted at:
Office of Health and Environmental Assessment
U.S. Environmental Protection Agency
Washington, DC 20460

NIST Technology Update

Licensing Opportunity

National Institute of Standards & Technology
(Formerly the National Bureau of Standards)
U.S. Department of Commerce, Gaithersburg, MD 20899

Clinical Instruments Can Be Sterilized In Seconds

The time required to sterilize dental and medical instruments can be reduced from hours to seconds by an innovative process developed at NIST. The new method disinfects instruments completely in 30 seconds when they are treated by a microwave-generated gas plasma produced in a container that holds the instruments inside a conventional microwave oven. The new technique should help health-care professionals improve patient care, and it may reduce the damage to expensive instruments caused by repeated exposure to traditional sterilization methods. NIST scientists, Dr. Waldemar de Rijk, dentist and physicist, and Dr. John A. Tesk, leader of the Dental and Medical Materials Group, collaborated on the project. A patent application has been filed, and de Rijk hopes to work with industry to develop a practical appliance in which a gas plasma can be used routinely in a health-care facility.

FOR ADDITIONAL INFORMATION: Dr. Waldemar de Rijk, NIST, A 143 Polymer Bldg., Gaithersburg, Md. 20899; (301)975-6803.

NIH
Research & Technology
U.S. Department of Health and Human Services Public Health Service National Institutes of Health

Federal Laboratory Resource

Animal Cell Culture Collection

Principal Investigator:
Robert J. Hay, Ph.D.
Head, Cell Culture Department
American Type Culture Collection
12301 Parklawn Drive
Rockville, Maryland 20852
(301) 881-2600

Director:
Robert E. Stevenson, Ph.D.

Resources Provided

- *Animal Cell Cultures:* Early passage cultures and/or continuous cell lines from about 75 different species. Lines are available from the bovine, buffalo, cat, chicken, chimpanzee, deer, dog, dolphin, duck, ferret, fox, frog, gerbil, goat, goose, gorilla, guinea pig, hamster (Armenian, Chinese, and Syrian), horse, human, lion, marmoset, minipig, mink, mongoose, monkey (African green, owl, rhesus, and squirrel), moth, mouse, muntjac, orangutan, pig, quail, rabbit, raccoon, rat, salmon, sea lion, seal, sheep, tahr, turkey, turtle, viper, wallaby, and whale, plus other exotic species. Hybridomas producing monoclonal antibodies to various cellular, humoral, and microbial antigens are also offered. A catalog that includes data, references, and recommended culture media is available without charge. Data bases and online telecommunication are offered through the DIALCOM system.
- *Other Services:* Services available include testing cell lines for mycoplasma and other microbial contaminations, verification of species of origin by isoenzymology, cytogenetic evaluation or fluorescent antibody staining, the production of working stocks of cell lines, and development of new lines from peripheral blood or other tissue samples. A laboratory workshop on cell line preservation and quality control procedures is also offered periodically.

Research Emphasis or Application

- *Basic Objective:* To acquire, preserve, and authenticate for distribution human and other animal cell lines of utility for the biomedical and biotechnological communities.
- *Current Research:* Development and characterization of cell lines from human normal and tumor tissues. Development of hybridomas producing monoclonal antibodies to cellular antigens. Application of new recombinant and molecular techniques for cell line identification in collaboration with scientists at the National Cancer Institute.

NIH
Research & Technology
U.S. Department of Health and Human Services Public Health Service National Institutes of Health

Federal Laboratory Resource

Mouse Mutant Gene Resource

Principal Investigator:
Muriel T. Davisson, Ph.D.
The Jackson Laboratory
Bar Harbor, Maine 04609
(207) 288-3371 x340

Resources Provided

• *Animals:* Mice with specific genes in various categories, including:

1. Growth and endocrine: congenital goiter (*cog*), disorganization (*Ds*), dwarf-J (dw^J), hypothyroid (*hyt*), sex reversal (*Sxr*) (= T_p(Y)1Ct), testicular feminization (*Tfm*), tubby (*tub*).

2. Neurological and ocular: aphakia (*ak*)*, ataxia (ax^J)*, blind sterile (*bs*), dilute-neurological (d^n), Dickie's small eye (*Dey*), ducky (*du*), gyro (*Gy*), hotfoot-4J (ho^{4J}), jittery (*ji*), lurcher (*Lc*), lethargic (*lh*), myotonia (adr^{mto}), myotonia-2J ($adr^{mto\text{-}2J}$), nuclear cataract (*nuc*), ocular retardation-J (or^J)*, oscillator (*ot*), polysyndactylism (*Ps*), quivering-3J (qv^{3J}), rabbit (*rb*), shaker-1 (*sh-1*), shambling (*shm*), sightless (*Sig*), tumbler-2J (tb^{2J}), tottering (*tg*), leaner (tg^{la}), trembler-J (Tr^J).

3. Skeletal: brachypodism-J (bp^J), belly spot and tail (*Bst*), droopy-ear-H (de^H), head blebs (*heb*), meander tail-2J (mea^{2J}), oligosyndactylism (*Os*), polysyndactyly (*Ps*), pudgy (*pu*), rachiterata (*rh*), rib vertebrae (*rv*), hairpin tail (T^{hp}), brachyury-2J (T^{2J}), tailkinks (*tk*), ulnaless (*Ul*), vestigial tail (*vt*).

4. Immunological and hair: balding (*bal*), bare-patches (*Bpa*), hairy ears (*Eh*), repeated epilation (*Er*), fur deficient (*fd*), frizzy (*fr*), furless (*fs*), fuzzy (*fz*), generalized lymphoproliferation disease (*gld*), greasy (*Gs*), harlequin (*Hq*), nude (*nu*)*, streaker (nu^{str}), plucked (*pk*), rex (*Re*), scant hair (*sch*), sparse-fur (*spf*), tabby (*Ta*), velvet coat (*Ve*), waved-2 (*wa-2*).

5. Pigment: white-bellied agouti (A^w), white-bellied agouti-J ($A^{w\text{-}J}$), white-bellied agouti-15J ($A^{w\text{-}15J}$), beige-2J (bg^{2J})*, albino-9J (c^{9J})*, chinchilla (c^{ch}), chocolate (*cht*), cocoa (*coa*), dominant brown (*Dbr*), dilute (*d*), dense-2J (d^{+2J}), grizzled (*gr*), leaden (*ln*), mahoganoid (*md*), mocha-2J (mh^{2J}), blotchy (Mo^{blo}), tortoise shell (Mo^{to}), pewter (Mo^{pew}), pewter-2J ($Mo^{pew\ 2J}$), ochre (*Och*), pink-eyed dilution (*p*), pink-eyed dilution-J (p^J), ruby-eye 2J ($ru\text{-}2^J$), sepia (*sea*), contrasted (Sl^{con}), slaty (*slt*), tabby (*Ta*), tabby-Bailey (Ta^{By}), tabby-2J (Ta^{2J}), taupe (*tp*)*, taupe-3J.

6. Kidney: Congenital progressive hydronephrosis (*cph*), congenital polycystic kidney (*cpk*), kidney disease (*kd*).

*These stocks are available from the Frozen Embryo Repository. There is a surcharge for embryo recovery in addition to the regular cost of the mice.

Mice with chromosomal aberrations:

1. Inversions: *In(X)1H.*

2. Robertsonian chromosome: *Rb(10.11)8Bnr.*

3. Reciprocal X-autosomal translocations: *T(X;4)37H, T(X;11)38H, T(X;16)16H.*

4. Insertional translocations: *Is(In7;X)1Ct, Is(7;1)40H.*

5. Reciprocal autosomal translocations: *T(1;2)5Ca, T(1;7)40H, T(1;9)27H, T(1;9)5Ei, T(1;13)70H, T(1;17)190Ca, T(2;3)24H, T(2;4)1Ca, T(2;4)Sn, T(2;4)13H, T(2;6)7Ca, T(2;8)26H, T(2;9)7Ei, T(2;9)11H, T(2;11)30H, T(2;12)1Ei, T(2;16)28H, T(2;17)6Ei, T(3;4)5Rk, T(3;12)30Rk, T(4;8)36H, T(5;8)3Rk, T(5;12)31H, T(5;13)264Ca, T(7;15)9H, T(7;18)50H, T(7;19)145H, T(8;16)17H, T(9;17)138Ca, T(10;18)18H, T(10;13)199H, T(11;13)3Ei, T(11;19)42H, T(13;17)2Ei, T(16;17)43H.*

6. Monosomy: XO.

Several linkage testing stocks and inbred strains including LDH2/Ei *Ldh-2[1]*, CASA/Rk, and CAST/Ei (*Mus castaneus*), IDH2/Ei *Idh-2[b]*, IS/CamRk, MOR/Rk *Mor-1[b]*, SOD1/Ei *Sod-1[1]*, SF/CamEi, SK/CamEi, PERA/Ei (PERU-Atteck), PERC/Ei (PERU Coppock), and MOLF/Ei and MOLG/Dn (*Mus molossinus*).

• *Contact Persons:* Muriel T. Davisson, Ph.D., or Eva M. Eicher, Ph.D., (207) 288-3371 x 340 or 240.

Research Emphasis or Application

- *Basic Objectives:* To discover new inherited endocrine, neurological, and immunological mutations of the mouse; to maintain as breeding pairs and preserve as frozen embryos a number of established mouse mutations and chromosomal aberrations; to develop genetically suitable stocks of new and established mouse mutations for use in biomedical research; and to make these mutant stocks available to interested investigators in the scientific community.
- *Current Research:* Physiological and genetic analysis of several new recessive mutations affecting the thyroid gland, the central and peripheral nervous systems, muscle cells, embryological development and reproduction; genetic analysis of several named mutations not yet located on the chromosomal map, including mutations affecting the kidney, neurological mutations, and skeletal development mutations; allelism testing and linkage analysis of a number of new mutations.

NIH
Research & Technology
Federal Laboratory Resource
U.S. Department of Health and Human Services Public Health Service National Institutes of Health

Bacteriology Collection

Coprincipal Investigator:
Robert L. Gherna, Ph.D.
Head, Department of Bacteriology
American Type Culture Collection
12301 Parklawn Drive
Rockville, Maryland 20852
(301) 881-2600

Director:
Robert E. Stevenson, Ph.D.

Resources Provided

- The bacterial collection currently maintains over 13,000 strains representing most of the recognized species. The collection also has over 550 bacteriophages and holds over 1,400 type strains, by far the largest collection of authentic type cultures. The collection maintains and distributes other strains such as those used in the production or assay of antibiotics, vitamins, vaccines, and amino acids; antisera, antitoxins, enzymes, organic chemicals, foods, etc; chemical transformations; genetics, molecular biology, and ecological studies; teaching and research. A catalog that includes media formulations, strain histories, data and special applications is available without charge.

Research Emphasis or Application

- *Basic Objective:* Acquisition, preservation and authentication of bacterial strains and bacteriophages for distribution to the scientific community. Compilation of strain data arising from authentication of strains for the establishment of a data base that can be queried by the scientist.
- *Current Research:* Development of optimum methods for the preservation of fastidious bacteria; taxonomic analyses of various groups of bacteria using phenotypic and genotypic characteristics. Development of probabilistic matrices for computer-aided identification systems.

NIH
Research & Technology
U.S. Department of Health and Human Services Public Health Service National Institutes of Health

Federal Laboratory Resource

Animal Models for Comparative Medical Research

Principal Investigator:
David J. Prieur, D.V.M., Ph.D.
Professor of Veterinary Microbiology
and Pathology
Washington State University
Pullman, Washington 99164-7040
(509) 335-6032

Resources Provided

- *Animals and Biological Materials:* Animals, tissues, and other specimens are provided to the extent available from these animal models: the Chediak-Higashi syndrome of cattle and cats; myopathy of Labrador retriever dogs (canine periodic paralysis); Ehlers-Danlos syndrome of dogs; lysozyme deficiency of rabbits; combined immunodeficiency in horses; inherited prepuberal diabetes mellitus in Keeshond dogs; bovine acrodermatitis enteropathica; ovine beta galactosidase deficiency; familial canine dermatomyositis; inherited feline tremors (feline cerebellar disease); tottering and quaking mutant mice.
- *Other Services:* Information on animal models investigated by the resource staff (see *Current Research*). The resource staff is also interested in having other animal models referred for further investigation or development.
- *Contact Person:* David J. Prieur, D.V.M., Ph.D., (509) 335-6032.

Research Emphasis or Application

- *Basic Objectives:* To locate animals with genetic diseases homologous or analogous to those occurring in people; to define and characterize the disorders; to do fundamental research on the diseases and to disseminate the models to the research community; utilize the diseases to develop methods applicable to the diagnosis or treatment of human genetic diseases.
- *Current Research:* The Chediak-Higashi syndrome of cattle and cats; myopathy of Labrador retriever dogs (canine periodic paralysis); lysozyme deficiency of rabbits; combined immunodeficiency disease of foals; inherited feline tremors (feline spinocerebellar disease); inherited prepuberal diabetes mellitus in Keeshond dogs; bovine acrodermatitis enteropathica; canine chromosomal fragile sites; ovine beta galactosidase deficiency; tyrosinemia of mink; familial canine dermatomyositis; canine von Willebrand's disease; tottering and quaking mutant mice.

NIH
Research & Technology
U.S. Department of Health and Human Services Public Health Service National Institutes of Health

Computer System Rapidly Analyzes Sperm Movement

A computer system that provides unbiased sampling and a rapid and accurate analysis of sperm movement has been developed by researchers at the Oregon Regional Primate Research Center's department of reproductive biology and behavior in Beaverton.

According to senior research associate Donald T. Stephens, sperm movement is traditionally measured by inspection, which is tedious and time-consuming. "Because of the limited number of cells that can be counted, the values determined by inspection are also highly subjective," Mr. Stephens says. He developed the system together with programmer Robert Hickman and senior scientist Dr. Dale D. Hoskins.

"The system offers a lot of potential opportunities for researchers doing basic research on sperm motility as well as diagnosticians working in zoos and on projects involving animal husbandry and human infertility," Mr. Stephens notes.

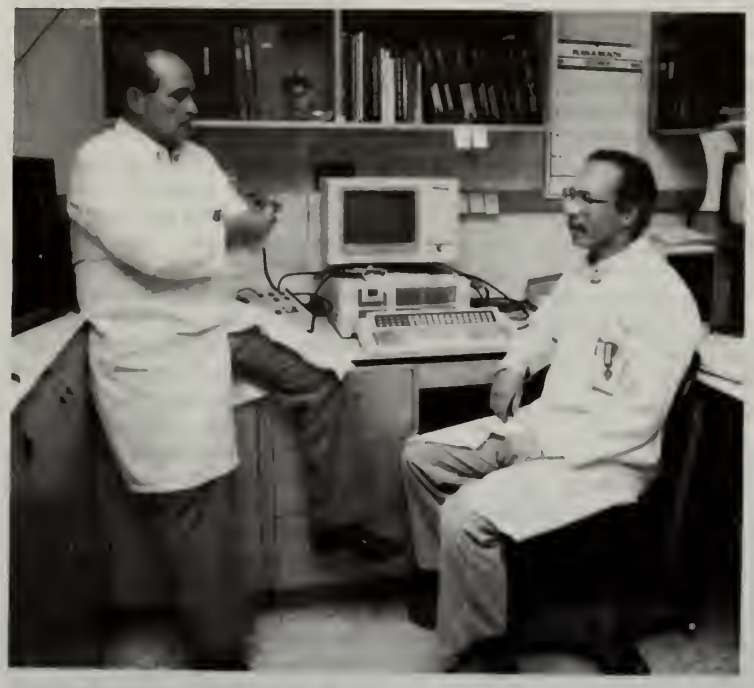
Sperm is produced in the testes and passes subsequently through a highly convoluted duct called the epididymis before being ejaculated. During its passage through the epididymis the sperm acquires the capacity to move forward that is necessary for reaching and fertilizing an egg.

Dr. Hoskins and his colleagues have studied the maturation of bovine sperm for more than a decade. They have shown that immature sperm cells from the first section of the epididymis, which is closest to the testes, are incapable of movement but can be induced to perform a vigorous, uncoordinated thrashing motion by chemicals that inhibit the breakdown of an intrinsic compound called cyclic AMP. In contrast, mature sperm cells from the last section of the epididymis are capable of straightforward motion.

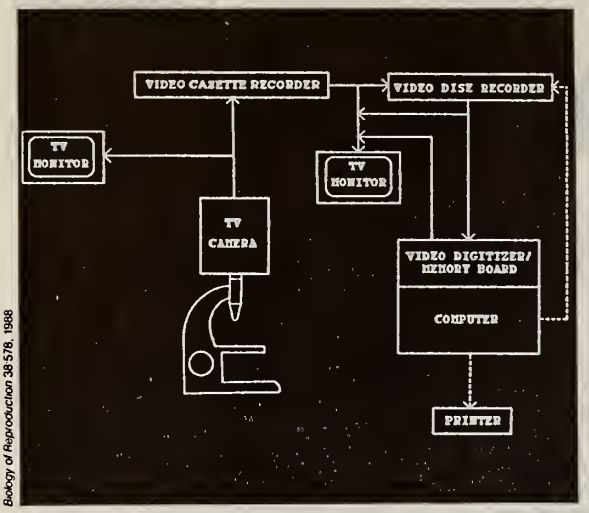
However, the investigators found that a protein called forward motility protein (FMP), which they had isolated from epididymal fluid, could convert the uncoordinated thrashing of immature sperm to a more orderly forward motion. In addition to propelling the sperm more directly forward, FMP causes the beating of the sperm tail, or flagella, to become more regular, according to Dr. Hoskins.

The Oregon researchers developed the computerized assay system, called a computer-automated sperm motility assay (CASMA), to improve the speed and reproducibility of their studies on the mechanisms regulating sperm motility. The unit is composed of a microscope-mounted video camera, a high-resolution video disk recorder, a video digitizer/memory board mounted in an IBM 9000 microcomputer, and specially developed software.

To perform an assay the investigators isolate a sperm



Senior scientist Dr. Dale D. Hoskins (left) and senior research associate Donald T. Stephens of the Oregon Regional Primate Research Center in Beaverton have developed a computer-automated system for analyzing the motility of bovine sperm. The assay procedure may become important for studies of both animal and human infertility.



The computer-automated sperm motility assay system records sperm movement on video cassettes via a television camera attached to a microscope. The sperm tracks are subsequently digitized and transferred to a computer that analyzes the tracks for direction, linearity, and velocity.

Biology of Reproduction 38:578, 1988

sample, place it under the microscope at body temperature (37° C), and make 12 10-second video cassette recordings of an area containing 2 to 50 sperm cells at a rate of 60 frames per second. The images are subsequently transferred to the video disk, digitized by the computer, and stored in its memory.

The computer now searches the first frame of each recorded sequence for objects (sperm heads) that fit preestablished criteria for proper size and contrast. This sperm recognition procedure is repeated until the desired number of sperm cells has been found. The computer then advances the disk recorder one frame and repeats the sperm recognition procedure. This process is repeated until each sperm cell has been tracked through a 30-frame (½ second) sequence. Twelve such "takes" are analyzed, requiring 20 minutes total, in contrast to the 2 days previously required.

During the computerized tracking the original video images are replayed on the monitor, and the sperm heads being tracked are indicated by white dots. This slow-motion replay therefore allows the researchers to monitor the performance of CASMA. After all the tracks have been stored as data files, analyses of various sperm movements can be performed.

When the system was tested all measurements were compared with those performed manually on the same image sequences of sperm cells, and the two methods produced almost identical results. According to Mr. Stephens, accurately determining the linearity of sperm movement in a much shorter time than was previously possible is an especially valuable improvement. The investigators standardized the linearity measurements by producing a range of nonlinear movement patterns with various concentrations of a chemical, dibucaine, that changes sperm movements from linear to circular.

Although CASMA was developed for measuring bull sperm motility, sperm from other species with head shape and dimensions similar to those of bull sperm are equally measurable by the system, according to Mr. Stephens. Sperm cells of elephant, boar, rabbit, horse, and guinea pig are among the comparable types, but Mr. Stephens explains that CASMA also reliably analyzes the movement parameters of both human and fast-moving monkey sperm, which, like human sperm, have smaller heads.

Working with programmer Wayne Davison, Mr. Stephens and Dr. Hoskins now have almost completed a prototype of a system for sequential flagellar position analysis and movement characteristics. "We realized that the very high image quality and framing rate attained with the current CASMA system makes flagellar movement analysis possible," Mr. Stephens says. When completed the system will be the first to provide quantitation of both head and flagellar movements.

When the production of the IBM 9000 microcomputer was discontinued, Mr. Stephens and his colleagues had to adapt another type of computer to the system. They are now in the process of adapting the Macintosh II, a 32-bit microcomputer. "The Macintosh is faster and will ultimately give better performance than the original computer," comments Mr. Stephens, adding that the changeover "will take about 3 months."

Mr. Stephens adds that CASMA is affordable: "The hardware for our first system cost about $35,000—that was in 1983-1984—but since then prices have come down. We are also refining the system so it will run on less expensive equipment."

Additional reading:

1. Stephens, D. T., Hickman, R., and Hoskins, D. D., Description, validation, and performance characteristics of a new computer-automated sperm motility system. *Biology of Reproduction* 38:577-586, 1988.
2. Makler, A., MacLusky, N., Chodos, A., Haseltine, F., and DeCherney, A., Rapid microcomputer-based analysis of semen characteristics from photographs taken by the MEP method. *Archives of Andrology* 12:91-95, 1984.
3. Acott, T. S., Katz, D. F., and Hoskins, D. D., Movement characteristics of bovine epididymal spermatozoa: Effects of forward motility protein and epididymal maturation. *Biology of Reproduction* 29:389-399, 1983.

The studies described in this article were supported by the National Institute of Child Health and Human Development, the Biomedical Research Support Grant Program and the Animal Resources Program of the NIH Division of Research Resources, the Mellon Foundation, and the Oregon Medical Research Foundation.

For Additional Information:

To locate information or professional contacts on this effort, contact:

Research Resources Information Center
1601 Research Boulevard
Rockville, MD 20850
(301) 984-2870

Refer to Volume XIII, No. 4/TN

Natural Resources Technology & Engineering

Testing & Instrumentation

0990 Gas Outburst Predictor

Gas Outburst Predictor

Objective

Improve the safety of salt mine workers by providing a means for quickly identifying areas within the mine that show an increased potential for gas and salt outbursts.

Approach

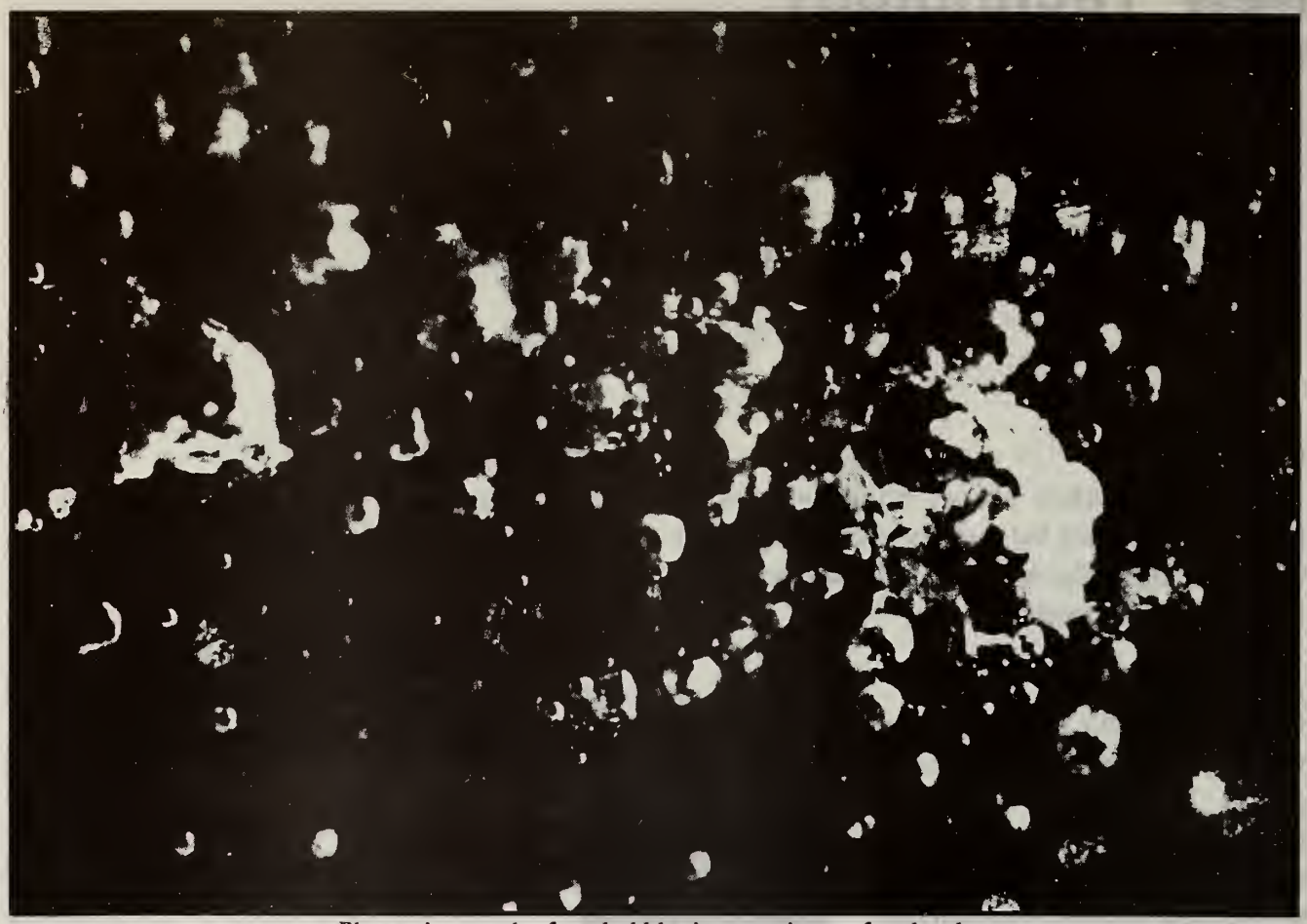
Outbursts occur in salt mines when a high-pressure pocket of gas is intercepted during the mining process, resulting in a sudden and sometimes catastrophic expulsion of gas and salt. In one case, the amount of gas released through such an event caused an explosion that resulted in five fatalities. The U.S. Bureau of Mines has designed and developed a gas outburst prediction system that can quickly determine the potential instability of areas within rock salt mines. The determination is based on noise measurements obtained from samples of the salt as they are dissolved in water. This system improves upon technology currently available because it provides information in only a few minutes instead of in several days. In addition, present prediction systems are not only time consuming, but expensive because they require laboratory conditions and highly trained personnel to operate them and determine results.

How It Works

The U.S. Bureau of Mines gas outburst predictor system provides information on the amount of gas contained in bubbles within a salt sample. The system is based on the theory that a direct positive relationship exists between the volume of gas in domal rock salt formations and the level of noises emitted when samples of salt are dissolved in water. By measuring the noise, a determination can be made of the potential for an outburst to occur prior to interception by mining.

The U.S. Bureau of Mines gas outburst predictor system.

The Bureau's gas outburst prediction system provides the same results within minutes that conventional predictor systems can provide only



Photomicrograph of gas bubbles in a specimen of rock salt.

after days. In addition, the Bureau's system does not require laboratory conditions or highly trained personnel. The only cost associated with the predictor, other than the cost of the equipment (about $9500 per system), is personnel time. When used during cooperative tests, individual mines have realized a cost savings of about $2000 per month by using the gas outburst predictor instead of previously developed techniques. Another big advantage of the Bureau's system is timeliness. Mine operators can obtain needed information within minutes to ensure that mine plans are properly and safely modified.

Test Results

The gas outburst predictor has been successfully demonstrated at operating domal salt mines. It is currently being used on a routine basis as part of the daily safety program of several mines.

Patent Status

The U.S. Department of the Interior holds a patent on the predictor system, U.S. patent 4,679,435. For additional information about this patent or on patent licenses, please contact the U.S. Bureau of Mines, Office of Technology Transfer, 2401 E Street, NW., M.S. 6201, Washington, DC 20241.

For More Information

For additional information about the Bureau's gas outburst predictor system, please contact the principal investigator for this research:

Thomas E. Marshall
U.S. Bureau of Mines
Pittsburgh Research Center
P.O. Box 18070
Cochrans Mill Road
Pittsburgh, PA 15236
Tel: (412) 892-4366

Physical Sciences

0991 Frequency Tables for Carbon Monoxide Lasers

0992 Hot Electrons Could Improve Photoelectrochemical Cell Efficiencies

0993 Magnetic-Flux-Compression Cooling Using Superconductors—Leakage of heat would be reduced.

0994 Error-Compensated Telescope—A small correcting mirror would be relatively inexpensive. (Licensing Opportunity)

0995 Pilot Plant Makes Oxygen Difluoride—Equipment processes the toxic, difficult-to-make substance efficiently and safely.

Testing & Instrumentation

0996 New Calibration Facility Monitors Sunphotometers

0997 Apparatus Makes Precisely Saturated Solutions—Measurements of saturation conditions are accelerated. (Licensing Opportunity)

0998 Continuously-Variable Vernier Scale—An easily fabricated device increases precision in reading graphical data. (Licensing Opportunity)

Other Items of Interest

0967 New Fluorescence-Based Chemical Indicator for Detecting Chloroform and Tricloroethylene

0990 Gas Outburst Predictor

NIST Technology Update

National Institute of Standards & Technology
(Formerly the National Bureau of Standards)
U.S. Department of Commerce, Gaithersburg, MD 20899

Frequency Tables for Carbon Monoxide Lasers

Heterodyne frequency measurements on carbon monoxide (CO) have been made at NIST to obtain new, highly accurate values for the molecular constants. Calculation and tabulation of 140 transition frequencies using the new values provide data with an order of magnitude improvement in the accuracy of the frequencies. The results of this work are tabulated in 12C16O Laser Frequency Tables for the 34.2 to 62.3 THz (1139 to 2079 cm-1) Region (TN 1321).

FOR ADDITIONAL INFORMATION: A copy of the report is available from NTIS, Springfield VA 22161; (703)487-4600.

NTIS order number: PB 89-193908/NAC
Price code: A03

Solar Energy Research Institute

Hot Electrons Could Improve Photoelectrochemical Cell Efficiencies

SERI researchers believe that the conversion efficiency of photoelectrochemical (PEC) cells can be increased by a factor of two if hot electrons can be used for fuels and chemicals production before their energy is lost in the cell.

The energy is lost within a few picoseconds (1 picosecond = 10^{-12} sec), and schemes must be developed to extract the energy before it is lost. Special semiconductor systems are being designed to accomplish this.

If researchers are successful, PEC cells could be used to convert sunlight to hydrogen through photolytic water splitting, and methane and methanol through photoreduction of carbon dioxide. Another application for PEC cells is in the photodecomposition of pollutants and toxins with photocatalytic semiconductor particles.

Contact: Dr. Arthur J. Nozik
(303) 231-1953

NASA Tech Brief
National Aeronautics and Space Administration
NASA's Jet Propulsion Laboratory, Pasadena, California

Magnetic-Flux-Compression Cooling Using Superconductors

Leakage of heat would be reduced.

A proposed magnetic-flux-compression refrigeration system would produce final-stage temperatures below 4.2 K. Like other magnetic refrigeration systems, this one promises to be more efficient than mechanical and sorption refrigerators are at temperatures in this range. The proposed system should weigh less than do comparable liquid-helium-cooled superconducting magnetic refrigeration systems that operate below 4.2 K.

In the proposed system, the magnetic field would be compressed in an electromagnet made of one of the newly discovered superconductors that have transition temperatures above ~90 K. The higher operating temperatures (compared to those of other systems based on superconductivity) should reduce the size of, and demands upon, the refrigeration stages that cool the final stage. Because the heat would be lost from the magnet at a higher temperature, the low-temperature efficiency would be increased.

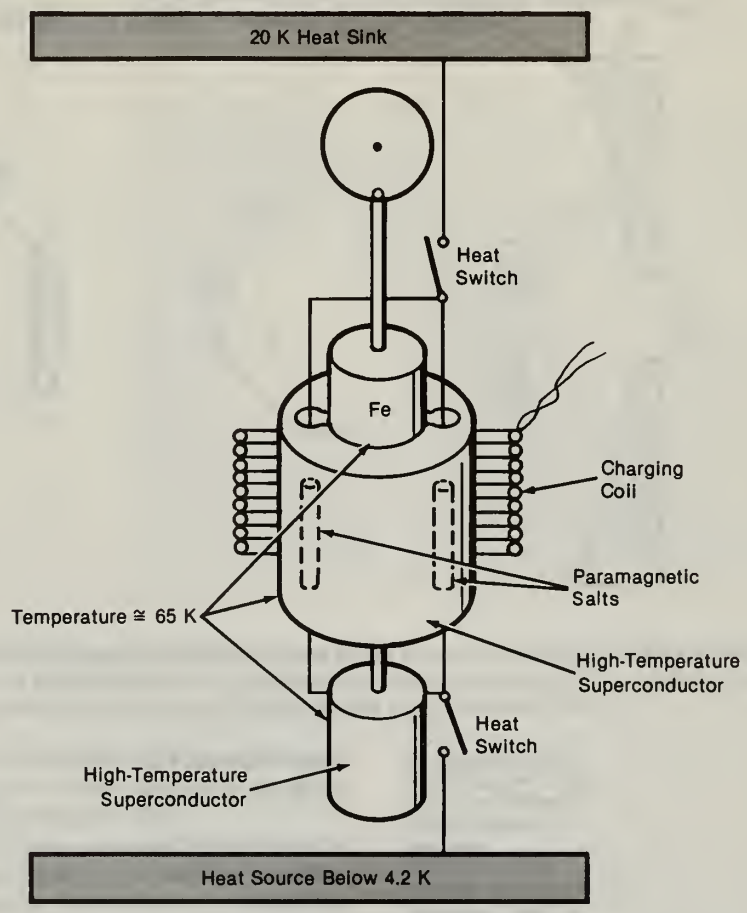
The final refrigeration stage (see figure) would typically include a body made of a high-temperature superconductor. Two small holes in the body would be connected to a large hole by a gap of small cross-sectional area. The small holes would contain a paramagnetic salt. A soft-iron cylinder and a superconducting cylinder would be placed in the large hole alternately during each refrigeration cycle.

During normal operation, this stage would be cooled below the critical temperature for superconductivity. However, to charge the stage initially (or to recharge the stage after a number of cycles of operation) with magnetic field, it would be temporarily heated above the critical temperature by an embedded heating coil while an external coil applies the charging magnetic field. During charging or recharging, the large hole would be occupied by the soft-iron cylinder to intensify the magnetic flux within it. After charging, the heating coil would be turned off, thus "turning on" the superconductivity and trapping the magnetic flux in the superconducting body.

The cyclic operation of the refrigerator would then begin. During the first half cycle, the superconducting cylinder would be inserted in the large hole to compress the magnetic flux through the gaps into the small holes, the lower heat switch would be opened, and the upper heat switch would be closed. The heat generated by the magnetization of the paramagnetic salt would be transferred through the upper heat switch into the 20 K heat sink.

During the second half cycle, the superconducting cylinder would be withdrawn and replaced by the soft-iron cylinder to draw the magnetic flux from the small holes back into the large hole. The upper heat switch would be opened and the lower heat switch closed so that the cooling of the paramagnetic salt due to demagnetization could be used to draw heat from the low-temperature heat sink or specimen to be cooled.

Only a small amount of magnetic flux should have to be supplied initially, and, because little magnetic flux is lost during each cycle, the need for recharging should be reduced. These features should reduce



The **Magnetic-Flux-Compression Refrigerator** would be the final cooling stage in a refrigeration system that produces temperatures below 4.2 K. The stage would combine the advantages of some newly discovered superconductors with those of cooling by magnetization and demagnetization of paramagnetic salts.

the leakage of heat and increase the energy efficiency of the system.

This work was done by Donald M. Strayer, Ulf E. Israelsson, and Daniel D. Elleman of Caltech for **NASA's Jet Propulsion Laboratory**.

Inquiries concerning rights for the commercial use of this invention should be addressed to the Patent Counsel, NASA Resident Office-JPL. Refer to NPO-17504/TN

FOR ADDITIONAL INFORMATION: *Contact: Director, Technology Transfer Division, P.O. Box 8757, BWI Airport, MD 21240; (301) 621-0100 Ext. 241*

REFER TO THE NUMBER LISTED AT THE END OF THIS ARTICLE

NASA Tech Brief
National Aeronautics and Space Administration

Licensing Opportunity

NASA's Jet Propulsion Laboratory, Pasadena, California

Error-Compensated Telescope

A small correcting mirror would be relatively inexpensive.

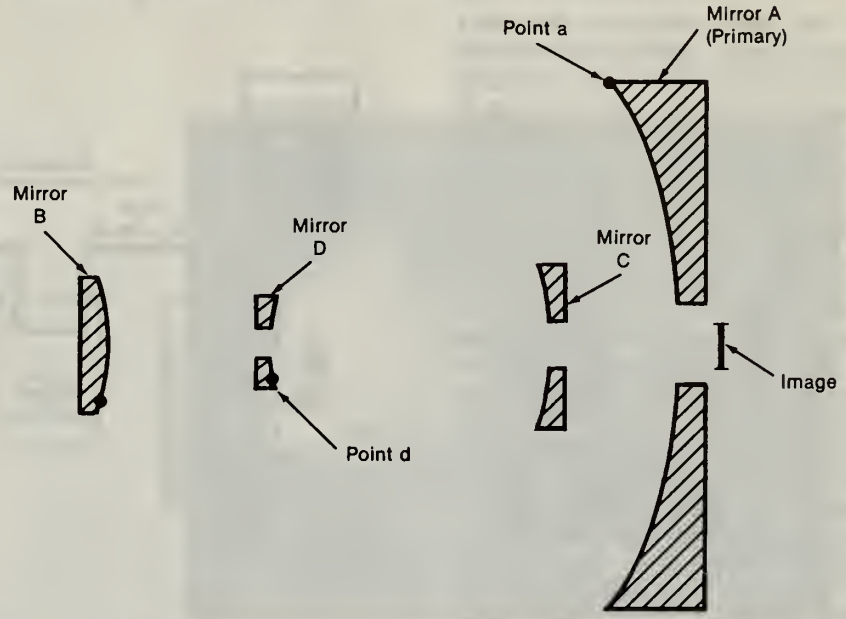
A proposed reflecting telescope would include a large, low-precision primary mirror stage and a small, precise correcting mirror. The correcting mirror would be machined under computer control to compensate for the error in the primary mirror. Because the second stage would be smaller, it would cost less to machine precisely and would maintain its shape more readily. Because the primary mirror would no longer have to be precise, it would no longer have to be made in one heavy piece to maintain its shape. Instead, it could be made of lightweight materials in deployable segments, without costly time-consuming polishing to final shape.

The correcting mirror would be machined by a diamond cutting tool. A computer would analyze interferometric measurements of the primary mirror to determine the shape of the surface of the correcting mirror needed to compensate for errors in the wave front reflected from the primary mirror and would command the position and movement of the cutting tool accordingly.

In a four-mirror version (see figure), mirror A is the primary mirror, the optical errors of which are to be corrected. Mirror B brings the light to an approximate focus in the hole in mirror D. Mirror C forms an exit pupil at mirror D, which is the error-correcting mirror. A tilt error at point *a* on mirror A can be corrected by a tilt at point *d* on mirror D so that the ray reflected from it arrives at the proper place in the image. Similarly, a piston error of a segment of mirror A can be compensated by a piston displacement of the corresponding part of mirror D.

This work was done by Aden B. Meinel, Marjorie P. Meinel, and John E. Stacy of Caltech for **NASA's Jet Propulsion Laboratory**. *For further information, Circle 26 on the TSP Request Card.*

This invention is owned by NASA, and a patent application has been filed. Inquiries concerning nonexclusive or exclusive license for its commercial development should be addressed to the Patent Counsel, NASA Resident Office-JPL. Refer to NPO-16869/TN.



Errors in the Wave Front Reflected From Mirror A would be corrected by compensating errors in the surface of mirror D. The corrections ensure that points in the image occupy the same relative positions in the image that they do in the field of view.

Jet Propulsion Lab.
NASA Resident Office
Technology Utilization Officer: Gordon S. Chapman
Mail Stop 180-801
4800 Oak Grove Drive
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Patent Counsel: Paul F. McCaul
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(818) 354-2240

FOR ADDITIONAL INFORMATION: *Contact: Director, Technology Transfer Division, P.O. Box 8757, BWI Airport, MD 21240; (301) 621-0100 Ext. 241*
REFER TO THE NUMBER LISTED AT THE END OF THIS ARTICLE

NASA Tech Brief
National Aeronautics and Space Administration
NASA's Jet Propulsion Laboratory, Pasadena, California

Pilot Plant Makes Oxygen Difluoride

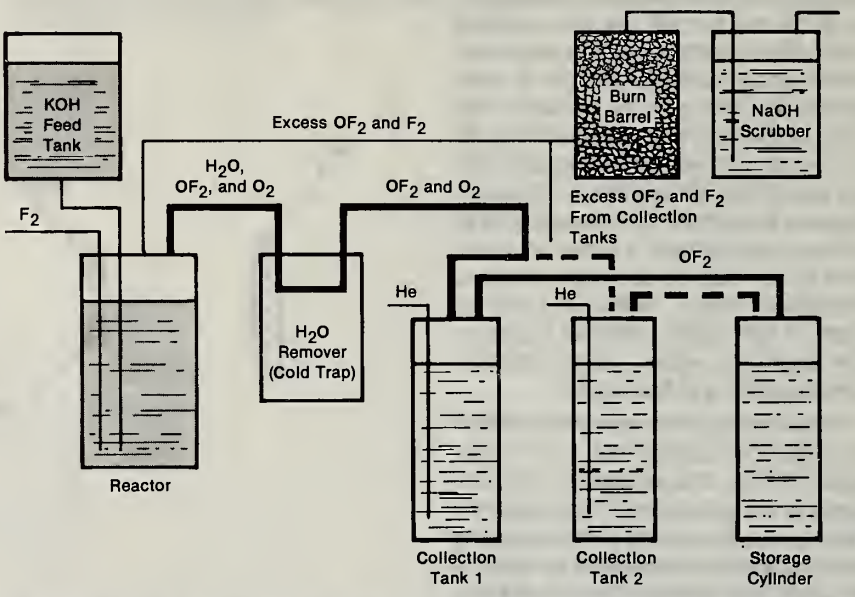
Equipment processes the toxic, difficult-to-make substance efficiently and safely.

A pilot plant makes oxygen difluoride, a highly-energetic, space-storable oxidizer that is not made commercially. The plant is designed to handle the reactants, product, and byproduct, most of which are highly reactive, corrosive, and toxic.

The plant fluorinates aqueous alkali to produce OF_2 in the reaction $2F_2 + 2KOH \rightarrow OF_2 + 2KF + H_2O$. The undesired reaction $2F_2 + 4KOH \rightarrow O_2 + 4KF + H_2O$ also consumes about half of the fluorine. The concentration of the KOH must be maintained at 2 percent, and the KOH solution must be kept cold. Because the potassium fluoride byproduct is toxic, it is treated with calcium hydroxide: $2KF + Ca(OH)_2 \rightarrow CaF_2\downarrow + 2KOH$. The calcium fluoride precipitate is nontoxic and can be discarded safely. The potassium hydroxide is recycled to the solution.

In the plant, the fluorine is bubbled through the chilled KOH solution in a reactor (see figure). The OF_2 and the O_2 from the competing reaction are passed through a cold trap to remove water. Another cold trap (not shown) also removes carbon dioxide, which is present as an impurity. The OF_2 and O_2 are then condensed in a collection tank. When a sensor indicates that the tank is filled nearly to capacity, that tank is disconnected and collection resumes in a second tank. The first tank is sparged with helium, which vaporizes the O_2 and leaves the OF_2 behind. The OF_2 is transferred to cylinders for storage.

Waste OF_2 and F_2 are sent to a stainless-steel barrel lined with ceramic insulation and filled with wood charcoal. In a spontaneous reaction, the charcoal burns in the toxic waste oxidizers. To prevent the escape of toxic gases, the barrel is vented through another drum filled with a dilute solution of NaOH.



Oxygen Difluoride Evolves Continuously from a reactor that contains potassium hydroxide in water at 0°C. The collection tanks are alternated; one is filled while the other is drained to a storage cylinder. Excess OF_2 and F_2 are dissipated in the combustion of charcoal in a burn barrel. The toxic byproduct, potassium fluoride, is reacted with calcium hydroxide to form the nontoxic calcium fluoride and to regenerate the potassium hydroxide.

The plant is constructed of stainless steel that has been passivated with fluorine gas. The valves have copper seats rather than plastic ones, which would react with the oxidizers. The plant is located in a test bay and is controlled from a remote console. Video cameras monitor the reactors. Microcoulombic sensors, in which traces of oxidant create a current proportional to the concentration, continuously check the test bay for leakage. The sensors can detect concentrations as low as 0.05 part per million, well below the maximum allowable concentration for humans. They respond rapidly, well before a human can detect the strong odor of OF_2.

The pilot plant consumes about 1 lb (0.45 kg) of fluorine per hour. It produces 0.38 to 5.0 lb (0.17 to 2.3 kg) of OF_2 per hour.

This work was done by Marshall F. Humphrey and Emil A. Lawton of Caltech for **NASA's Jet Propulsion Laboratory.** *NPO-17347/TN*

FOR ADDITIONAL INFORMATION: *Contact: Director, Technology Transfer Division, P.O. Box 8757, BWI Airport, MD 21240; (301) 621-0100 Ext. 241*
REFER TO THE NUMBER LISTED AT THE END OF THIS ARTICLE

Solar Energy Research Institute

New Calibration Facility Monitors Sunphotometers

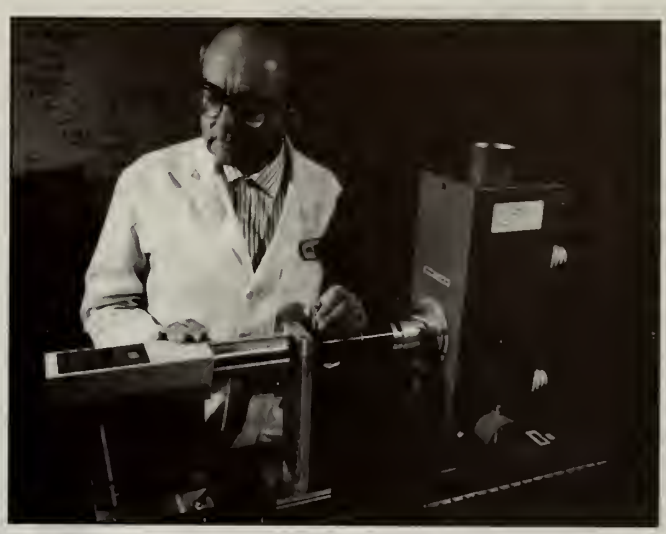
Much of the time and effort previously consumed in recalibrating sunphotometers now is being saved, thanks to a new SERI facility that monitors changes in the meters' calibration.

The Sunphotometer Laboratory Calibration Facility will periodically measure the sunphotometers to determine if they require the complex and time consuming calibration procedures that must be performed outdoors under nearly ideal sky conditions. Often a simple correction to the meters' calibration constant is all that is required.

Sunphotometers are used to measure sunlight and atmospheric optical conditions. These measurements determine the amount of dust, haze, and water vapor in the air and aid researchers in developing and monitoring the performance of solar cells.

Developed by SERI's Resource Assessment and Instrumentation Branch, the new facility uses a very stable, high-power light source focused into a beam to simulate sunlight. Special jigs enable measurements of the same meter to be repeated accurately from setup to setup.

The facility can accomplish interim calibrations of new sunphotometers by comparing them against previously calibrated instruments and can measure the optical and temperature response of developmental instruments under laboratory conditions.



SERI's Sunphotometer Laboratory Calibration Facility is saving the time once spent doing unnecessary calibrations.

Contact: Dr. Ted Cannon
(303) 231-7247

NASA Tech Brief
National Aeronautics and Space Administration
Marshall Space Flight Center, Alabama

Licensing Opportunity

Apparatus Makes Precisely Saturated Solutions

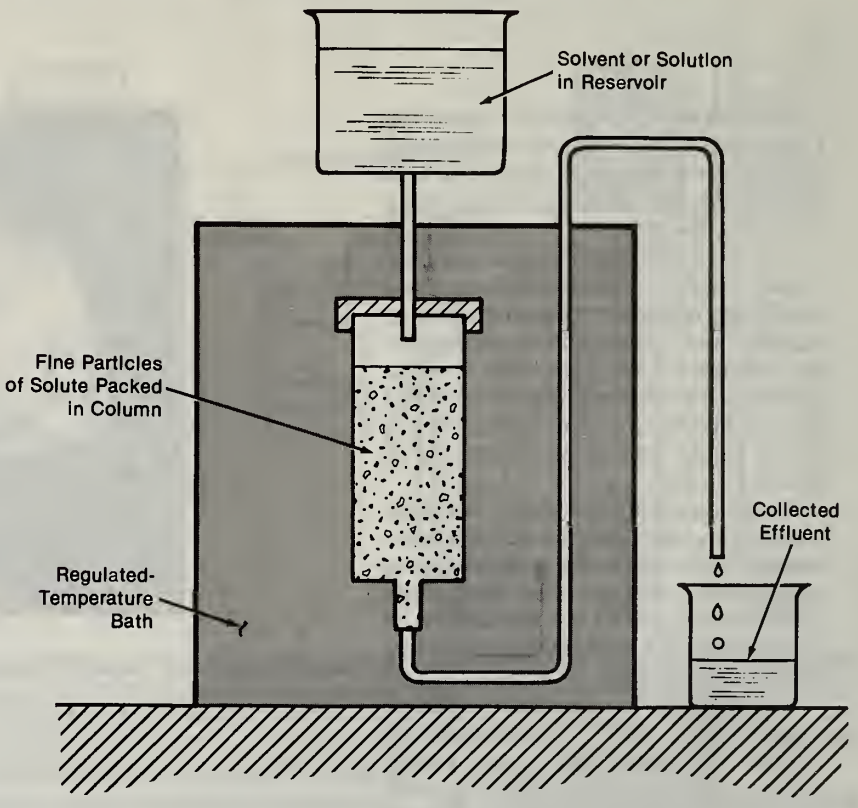
Measurements of saturation conditions are accelerated.

A simple laboratory apparatus establishes equilibrium conditions of temperature and concentration in solutions for use in precise measurements of the saturation conditions. With this equipment a typical measurement of the saturation concentration of a protein in solution can be established and measured within about 24 hours, whereas prior techniques and equipment required about 8 weeks for such a measurement. Thus, the apparatus is particularly useful for such repetitive measurements as those necessary to establish multiple-constituent or temperature-versus-concentration phase diagrams.

The apparatus (see figure) includes a regulated-temperature bath that maintains a column within 0.01 °C of the desired temperature. The column is packed with a slurry consisting of the solution and fine particles of the solute. The lower end of the column is plugged with fine glass wool to prevent particles of solute from falling out. The solvent or solution is fed from a reservoir into the upper end of the column, and the effluent from the lower end of the column is collected. The concentration of the solute in the effluent solution is measured by the applicable conventional technique.

Provided that the flow of solvent is slow enough, the effluent should be a saturated solution. If it is suspected that the solute in question crystallizes or dissolves too slowly to come to equilibrium with the solvent before the solution has passed along the column, then the flow is interrupted for the time necessary to establish equilibrium — usually 24 hours or less. Then the effluent is collected in several volume fractions, each about one-twentieth of the volume of the column, and the concentrations in these fractions are measured. The temperature can then be changed to the next value, while the flow remains stopped to establish the new equilibrium.

The nearness to saturation in a simple column can be examined by use of two columns operating at the same temperature. The reservoir of one column is filled with a supersaturated solution, while that of the other column is slightly undersaturated. The concentrations of solute in the effluents of the two columns then represent outer limits between which the saturation concentration must lie. If the two concentrations differ by less than the limits of accuracy of the measurements, then it can be assumed that equilibrium is established in the column. If the two concentrations differ, then the flow must be stopped for a longer time to assure equilibrium.


Solvent or Solution in Reservoir
Fine Particles of Solute Packed in Column
Collected Effluent
Regulated-Temperature Bath

A **Precisely Saturated Solution** is made by passing a solvent or solution slowly along a column packed with the solute at a precisely controlled temperature. If necessary, the flow is stopped for an experimentally determined interval to allow equilibrium to be established in the column.

This work was done by Marc L. Pusey of **Marshall Space Flight Center**.

Inquiries concerning rights for the commercial use of this invention should be addressed to the Patent Counsel, Marshall Space Flight Center [see page 18]. Refer to MFS-28280.

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NASA Tech Brief
National Aeronautics and Space Administration
Langley Research Center, Hampton, Virginia

Licensing Opportunity

Continuously-Variable Vernier Scale

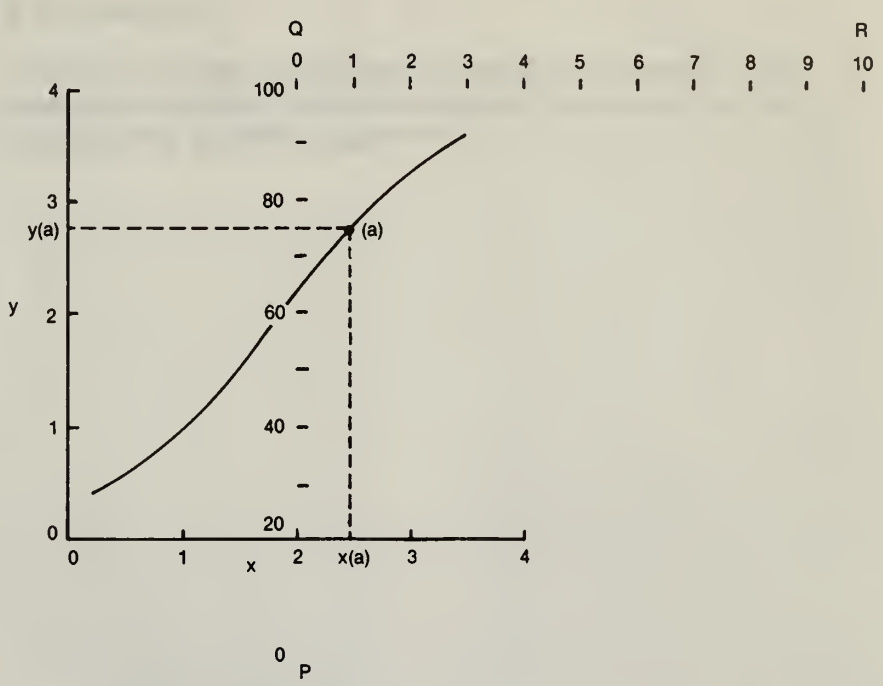
An easily fabricated device increases precision in reading graphical data.

The continuously-variable vernier scale (CVVS) is designed to provide greater accuracy to scientists and technologists in reading numerical values from graphical data. It is placed on the graph and used to interpolate the coordinate value of a point on a curve or a plotted point on a figure within a division on each coordinate axis.

A typical construction and use of the CVVS are shown in the figure. A baseline PQ is constructed of arbitrary length, but it should be about 10 times the distance to be interpolated. Next, the scale line QR is constructed perpendicular to PQ. For convenience, QR may be equal in length to PQ. Then, 10 equally spaced divisions are marked off on the scale line QR, and straight lines are drawn from P.

The CVVS is overlaid on a plotted curve as shown so that the two legs of the triangle, PQ and PR, span the division on the *x* axis that includes the projected intercept *x(a)* of point *(a)*. Note that this intercept falls between lines 4 and 5 of the geometric overlay. Therefore, *x(a)* can be more closely estimated as 2.49 instead of 2.5. If the scale is then rotated by 90° and the above procedure is repeated for the appropriate division on the *y* axis, the *y* coordinate, *y(a)*, is more closely estimated as 2.76 instead of 2.8. To make it easier to line up the baseline with a coordinate axis and with the line that projects the point to one of the axes, faint lines can be drawn parallel to both axes.

The CVVS can also be used to interpolate a logarithmic scale if a logarithmic scale is constructed on the scale line. It can also be used to change the scale of a figure by changing the scale of the coordinate axes on that figure.



The CVVS in This Case is used to read the *x* and *y* coordinates of point *(a)* more precisely as 2.49 and 2.76, respectively.

For durability and clarity, the CVVS can be constructed on thin, clear, plastic material. It is a simple, inexpensive device that can readily meet the needs of scientists and technologists in making better estimates of points on plotted figures that are published in the literature. The CVVS requires neither the measurement of line segments where the projection of the point intersects a division nor a calculation to quantify the projected value. It is a very flexible device that can be constructed with any kind of scale. It is very easy to use, requiring no special equipment of any kind, and can save a considerable amount of time if numerous points are to be evaluated.

This work was done by Irvin M. Miller of **Langley Research Center**. *No further documentation is available.*

This invention is owned by NASA, and a patent application has been filed. Inquiries concerning nonexclusive or exclusive license for its commercial development should be addressed to the Patent Counsel, Langely Research Center. Refer to LAR-13721/TN.

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NASA Tech Brief
National Aeronautics and Space Administration

Licensing Opportunity

Pilot Delays for Three Cockpit Controllers

The pilot effective delay increases with the system delay.

A report compares the pilot effective time delays measured in simulations of aircraft-control systems equipped with a Space Shuttle rotational hand controller and with two versions of a conventional stick-type hand controller. The report should be of interest to those concerned with the design of multiple-axis controllers in aircraft, armored vehicles, industrial machinery, and remote manipulators: the operator response or delay is critical to the stable and accurate operation of such systems.

Each of the three controllers was installed in a Space Shuttle cockpit simulator. The Space Shuttle hand controller had three degrees of freedom and nonlinear gearing. The more-conventional two-degree-of-freedom control stick had linear gearing and was equipped first with a stiff set of springs (heavy conventional stick), then with a softer set of springs (light conventional stick). The signal from the control stick was processed through the cockpit simulator with a 40-ms frame time, then sent to the critical-task tester. The total inherent delay between the pilot and the critical-task tester was 46 ms: 20 ms of sampling delay plus 26 ms of computation time.

The critical-task tester is a specialized electronic subsystem used to measure the pilot effective delay, τ_e, in response to a simulated first-order, closed-loop, compensatory tracking task. The critical task involves an unstable controlled element, the instability of which increases with time. Eventually, the system reaches a critical point beyond which the unstable system cannot be controlled. The amount of instability at that point gives a measure of τ_e.

The critical-task tester was used to measure the τ_e values in the roll and pitch axes in each of the three control configurations. Measurements in each case were made without additional system delay and with 250 ms of additional system delay. Thus, the total system delays were 46 and 296 ms, respectively. The test subjects were four test pilots and one nonpilot engineer.

The test data indicate that the heavy conventional stick had the lowest pilot effective time delays in both axes, both with and without the added system delay. The light conventional stick had τ_e values similar to those of the Space Shuttle controller. With all three controllers, τ_e increased with the added system delay. The increases in τ_e caused by the increase in system delay were more significant than the differences in τ_e among the three controllers: apparently, at large system delays one controller is about as good as another.

This work was done by Cynthia M. Privoznik and Donald T. Berry of **Ames Research Center**. *Further information may be found in NASA TM-86030 Price Code: A02 [N86-193224/NSP], "Comparison of Pilot Effective Time Delay for Cockpit Controllers Used on Space Shuttle and Conventional Aircraft."*

Copies may be purchased from the National Technical Information Service, Springfield, Virginia 22161, Telephone No. (703) 487-4650. Rush orders may be placed for an extra fee by calling (800) 336-4700.

Inquiries concerning rights for the commercial use of this invention should be addressed to the Patent Counsel, Ames Research Center. Refer to ARC-11797/TN.

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NASA Tech Brief
National Aeronautics and Space Administration

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Accuracy of Hot-Wire Anemometry In Supersonic Turbulence

The sensitivity of a hot-wire probe is compared to laser-induced-florescence measurements.

A report discusses the factors that affect the readings of a hot-wire anemometer in a turbulent supersonic boundary layer. The report presents a theoretical analysis of the responses of a hot-wire probe to changes in the flow; it also compares measurements by a hot-wire probe with measurements of the same flows by laser-induced fluorescence (LIF). Because LIF provides spatially and temporally resolved data on temperature, density, and pressure, it provides independent means to determine the responses of hot-wire anemometers to these quantities.

The usual objective of hot-wire anemometry is to measure the fluctuations in the mass flux, which is a product of flow speed and density. However, a hot wire does not respond to mass flux alone but to a combination of mass flux and total temperature, the total temperature being the temperature of a stagnation point in the flow. While comparisons of hot-wire anemometry with laser doppler velocimetry can provide partial speed calibrations, they provide no information on responses to fluctuations in density and temperature.

The basic equation of hot-wire anemometry is a linearized expression for the fluctuation in the voltage across a hot wire immersed in a flow:

$$(\Delta E/E) = S_\varrho(\Delta\varrho/\varrho) + S_U(\Delta U/U) + S_T(\Delta T/T)$$

where E = the voltage, ϱ = the density, U = the speed, T = the total temperature, S = the sensitivity to the subscripted quantity, and Δ denotes the fluctuation in the associated quantity. For mach numbers above 1.2 and Reynolds numbers above 20 (based on wire diameter)

$$S_\varrho \approx S_u = S_m$$

where $m = \varrho U$ = mass flux. The theoretical analysis explores the mathematical consequences of these equations under various assumed flow conditions to derive equations for three different calibration methods.

The first two methods are based on the concept of "single high overheat": the wire is operated at such a high temperature that it is sensitive only to mass flux and not to fluctuations of temperature in the flow. In the first method (the centerline method), measurements are made at the center line of a wind tunnel, where the flow is relatively free of disturbances. The stagnation pressure, and consequently the mass flux (but not the mach number), is varied from run to run. The second method (the boundary-layer method), which is less vulnerable to certain calibration errors, involves measurements of the boundary-layer flow with mass flow estimated from pitot-static measurements by the standard equations of compressible flow. The third method is more complicated: through measurements at various wire temperatures (multiple overheats) and statistical analysis, it provides for the determination of both S_m and S_T.

The three methods were applied to a mach 2.1 flow of nitrogen in a blowdown wind tunnel and compared with LIF measurements. As a result, the following conclusions were drawn:

- The boundary-layer and centerline methods give the same measurements of mass flux. The boundary-layer method minimizes errors, but the centerline method may be easier and more reliable for the measurement of some complicated flows.
- A hot wire can be operated at a single high overheat or at multiple overheats to measure fluctuations in the mass flux.
- If a high overheat is used to measure only fluctuations in mass flux, then root-mean-square fluctuations of temperature and density cannot be determined accurately.
- If multiple-overheat measurements are taken of the mass flux, the total temperature, and the correlation between them, and if there are no unsteady shocks or other sources of pressure fluctuations, then the root-mean-square fluctuations of temperature and density can be determined accurately.

This work was done by Pamela Logan, Robert L. McKenzie, and Daniel Bershader of **Ames Research Center.** *"Comparisons of HotWire and Laser-Induced Fluorescence Measurements Obtained in Supersonic Turbulence."*

Inquiries concerning the rights for the commercial use of this invention should be addressed to the Patent Counsel, Ames Research Center. Refer to ARC-11802/TN.

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